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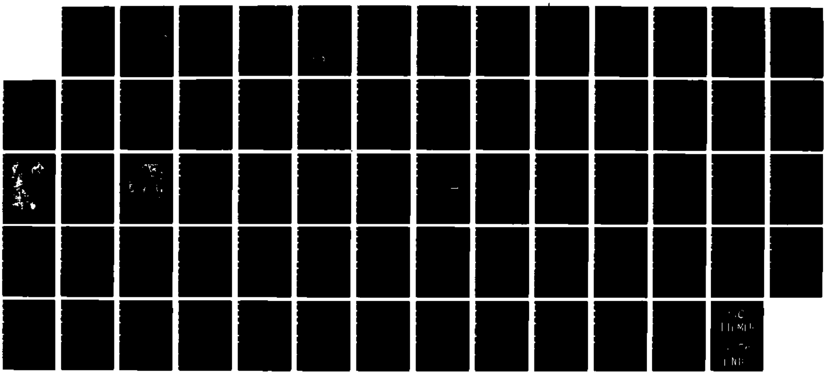

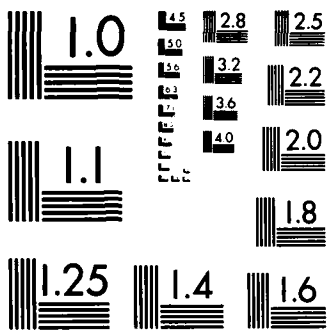

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Report No. DOT/FAA-PM-85-28

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Quarterly Technical Summary

AD-A165 221

Weather Radar Studies

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30 June 1985

Lincoln Laboratory

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

LEXINGTON, MASSACHUSETTS

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16. Abstract

FAA-funded Doppler weather radar activities during the period 1 April to 30 June 1985 are reported.

The test-bed Doppler weather radar system making measurements in Olive Branch, Mississippi, was fully operational. Additionally, the University of North Dakota C-band Doppler weather radar commenced measurements. Weather measurements were conducted on a number of cold front passages with attendant prefrontal lines of showers and thunderstorms and on scattered air mass thunderstorms. Some 17 microbursts were observed during the radar operation with the bulk of the microbursts occurring in late June. Thirty-one gust fronts were observed as well.

The University of North Dakota Citation aircraft made airborne turbulence measurements on eight days in the period mid-May to mid-June.

The Lincoln mesonet was fully operational throughout the period. The 1984 peak wind speed data from the mesonet and the Memphis International Airport LLWSAS data have been analyzed to determine ground level wind-shear characteristics in the Memphis area.

Doppler weather radar data from the National Center for Atmospheric Research JAWS program and the National Severe Storms Laboratory are being analyzed to develop low-altitude wind-shear detection algorithms. Analysis continued of the data collected in the 1983 Boston area coordinated aircraft-Doppler weather radar turbulence experiment.

Work continued on the development of weather radar products for the Central Weather Processor with particular emphasis on the correlation tracking and extrapolated weather map algorithms and an algorithm to generate vertical cross sections along a user specified axis.

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WEATHER RADAR STUDIES

I. INTRODUCTION

The principal areas of emphasis for the weather radar program over the period April-June 1985 have been:

(a) Continued development of a transportable Doppler weather radar test-bed to be utilized in a series of experimental programs during 1985-87.

(b) Reduction of data from the coordinated Doppler weather radar-aircraft experiments in the Boston, Massachusetts, area during the summer of 1983.

(c) Commencement of the first set of transportable test-bed experiments in the Memphis, Tennessee, area.

(d) Analyses in support of terminal weather surveillance by Doppler weather radar.

(e) Development of detailed specifications for certain Central Weather Processor (CWP) products to be generated by the NEXRAD system.

Progress in each of these above areas is described in the sections which follow.

II. TEST-BED DEVELOPMENT

The FAA-Lincoln Laboratory transportable test-bed (FL-2) is a NEXRAD-like Doppler radar which can be used for:

(a) Resolving the principal uncertainties in algorithms for detection and display of en route and terminal hazardous weather regions.

(b) Obtaining feedback from operationally oriented users on the utility of strawman end products for improving safety and efficiency of airspace utilization.

(c) Investigating Doppler weather radar-CWP interface issues, and

(d) Providing a data base for FAA specification of NEXRAD, terminal weather radar, and NEXRAD/CWP interfaces.

During the 1985 experiments, the transportable test-bed radar is being used in the following modes:

(a) As a terminal Doppler weather radar to detect low-altitude wind-shear (LAWS) and other hazards in an 'off-airport' mode using sector PPI scans with occasional RHI scans to focus on microburst/downburst detection in midair stage as well as outflow detection.

(b) As a NEXRAD 'network' sensor with a 5-min volume scan and principal focus on products of particular interest to the FAA such as turbulence, layered reflectivity, and LAWS.

(c) For 'scientific' data acquisition (as in the JAWS Project and NSSL Spring Programs) characterized by scientist-controlled scan patterns based on real-time three-moment displays.

Figure II-1 shows a block diagram of the test-bed.

The test-bed activity during the quarter focused on refinements in parallel with the execution of full scale measurements in the Memphis area.

A. RADOME

The radome is an inflatable dacron bag with a 55-foot diameter manufactured by Birdair. The radome is kept inflated by a dual blower system controlled by an external anemometer. Use of the radome commenced in August 1984 at Memphis. An unplanned deflation occurred in August 1984 as a result of lightning damage to the blower power system. Since that time, the radome has operated satisfactorily.

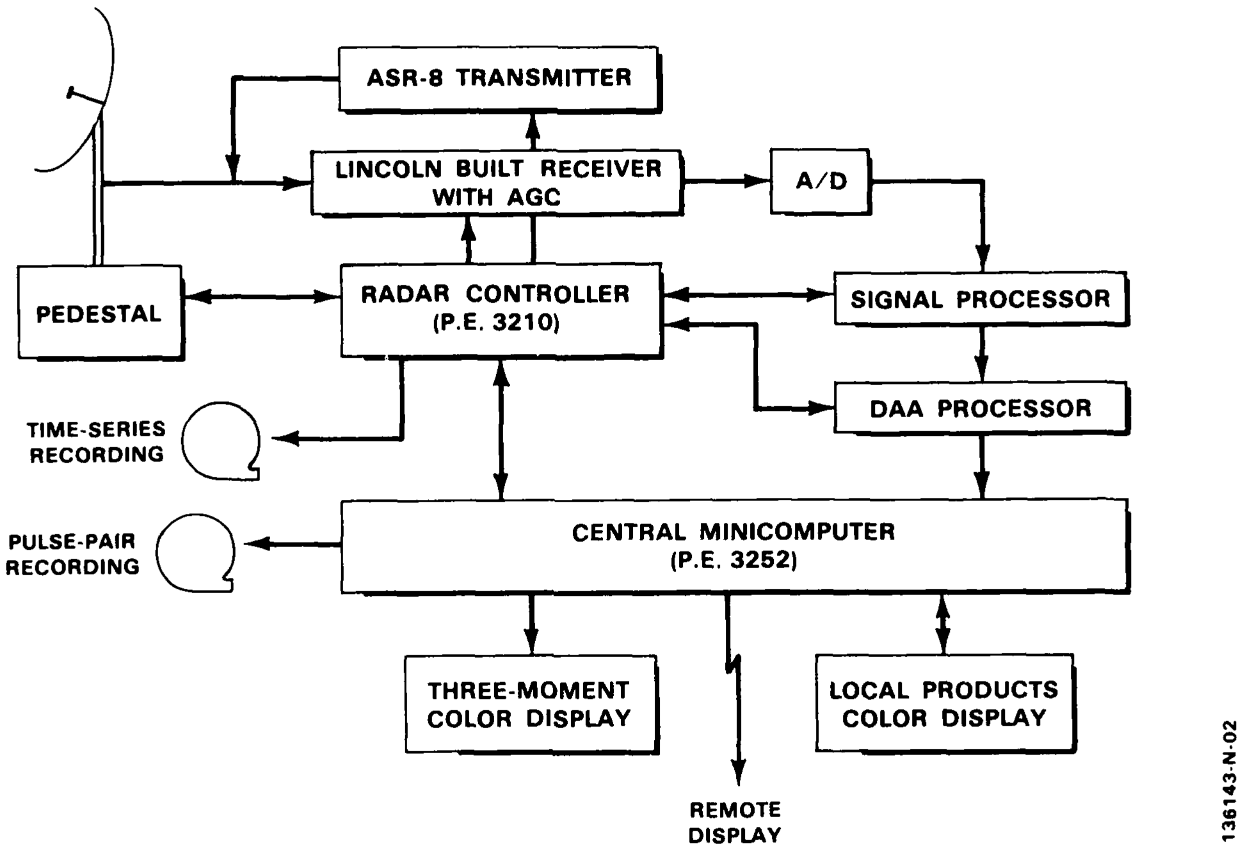

Figure II-1. Test-bed block diagram.

B. ANTENNA

The parabolic reflector antenna has a 33-foot diameter dish with illumination from the center horn to yield a 1° beamwidth with first sidelobes less than -25 dB. The dish (fabricated and tested by Hayes and Walsh) was installed at the Memphis site in 1984. The antenna has performed satisfactorily since that time. During this quarter, a new piece of waveguide was fabricated and installed above the rotary joints to correct a slight misalignment in the elevation joint. Subsequent measurements showed that the antenna system VSWR was not affected significantly.

C. ANTENNA MOUNT

Antenna pointing is accomplished by a Scientific Atlanta model mount that was modified by the Laboratory Control Systems Group to meet the NEXRAD Technical Requirement (NTR) for 15 deg/s^2 acceleration in both axes, 30°/s peak azimuth angular velocity, and 15°/s peak elevation velocity. The mount modifications included regearing, a forced flow oil lubrication for the gears and servo system changes. The mount commenced operation in Memphis in the summer of 1984. For much of the fiscal year, we have been modifying the servos and antenna control to achieve more nearly the scan sequence timing objectives described in the 31 December 1984 Quarterly Technical Summary.[1]

During the current quarter, circuitry was installed to digitize and pass to the 3210 computer the tachometer output voltages from the drive system. These velocity values will permit more effective use of velocity-based antenna control laws than were possible using velocities inferred from position data. Component values in the servo networks continued to be adjusted in connection with control program modifications in an effort to determine the most efficient control algorithms.

Extreme heat within the pedestal caused excessive thinning of the oil in the azimuth drive gearbox. Plans have been formulated to attach heat sinks to the box and blow cooling air across them.

During a routine maintenance session, it was discovered that a shear-pin in the elevation drive assembly had given way with the result that only one of the drive motors was connected. The only apparent effect was a very slight 'hunting' of the antenna due to the loss of torque bias. The cause of the shearing is unknown but a sticking brake is suspected.

D. TRANSMITTER/RECEIVER

The test-bed uses a production line ASR-8 transmitter and receiver on loan from the U.S. Navy with the Lincoln-developed 'instantaneous' automatic gain control (AGC) shown in Figure II-2. After some additional filtering was added to the modulator, the transmitter met with the objectives of an integrated instability residue of less than -50 dB. The transmitter/receiver has operated reliably since turn-on in 1984.

A problem was uncovered when *COHO phase-switching* in the receiver was implemented for the purpose of eliminating second-trip echos. A small amount of COHO leakage into the AGC system caused a slight dc-offset at the quadrature video ports. Circuitry was designed and installed to cancel the leakage, thus reducing the dc-offset to an acceptable level.

A chassis was installed in the control and display area to permit remote control of the transmitter and to monitor several functions connected with the RF and waveguide systems.

E. SIGNAL PROCESSOR

The signal processor is a Lincoln-built system that accomplishes AGC normalization and clutter suppression by finite impulse response (FIR) filtering and autocorrelation lag (0, 1, 2) estimation using fixed-point (16-bit) arithmetic. The signal processor completed testing of its basic processing capability in February and has been used routinely for all measurements in Memphis this calendar year.

Work continues on the test-bed signal processor's time series recording buffer. New diagnostics became available to enable complete functional testing of the buffer.

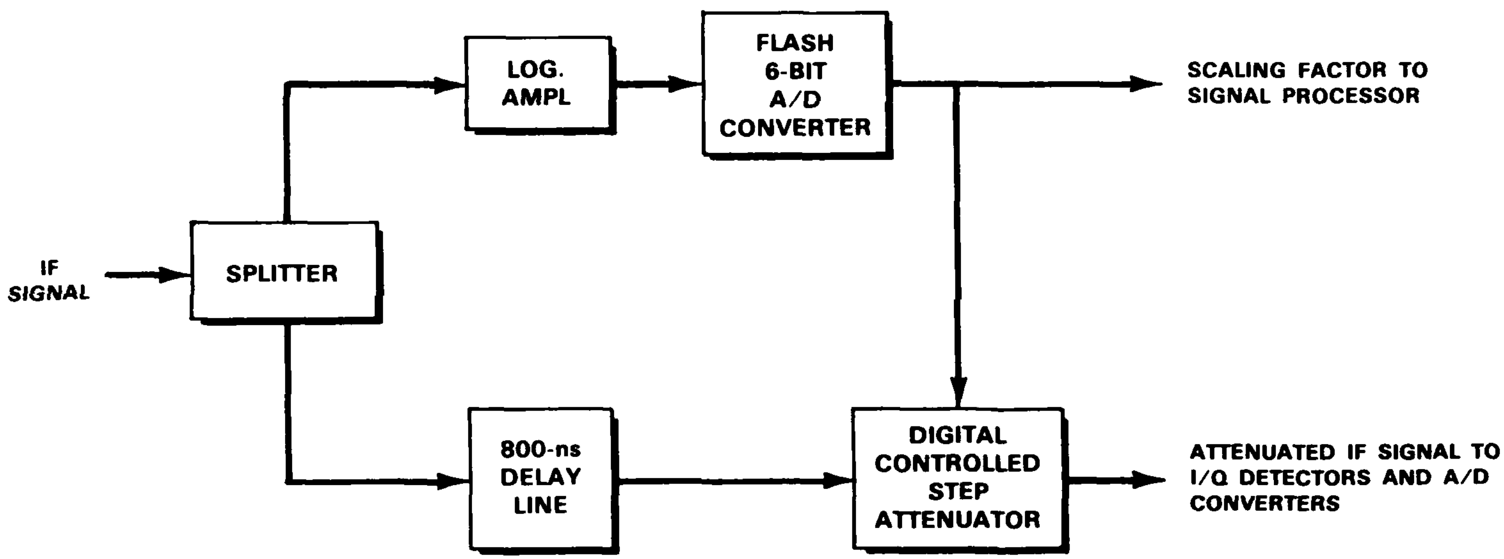

Figure II-2. 'Instantaneous' AGC system.

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Some timing circuit problems affecting autocorrelation reliability were discovered while debugging a spare autocorrelator. This problem will be resolved when the second signal processor becomes operational.

Construction and bench testing of the second signal processor is complete. The signal processor will be interfaced with a Perkin-Elmer 3242 computer at the Laboratory in the next quarter and testing will proceed.

Parts for the new radar simulator have been procured and the design is underway.

F. DATA ACQUISITION AND ANALYSIS (DAA) PROCESSOR

The DAA processor is a Lincoln-built multiprocessor, used to perform real-time processing of Doppler weather radar data. Figure II-3 shows a block diagram of the DAA. Three DAA processor systems currently exist — one in the weather radar test-bed for operational use, and two at the Laboratory for development.

Both the test-bed and Laboratory DAAs functioned reliably through the quarter. The third DAA has been completed and moved to Annex II (Lincoln Laboratory) and is beginning testing. This new DAA will alleviate greatly the conflicts arising from DAA usage both for software and hardware debugging.

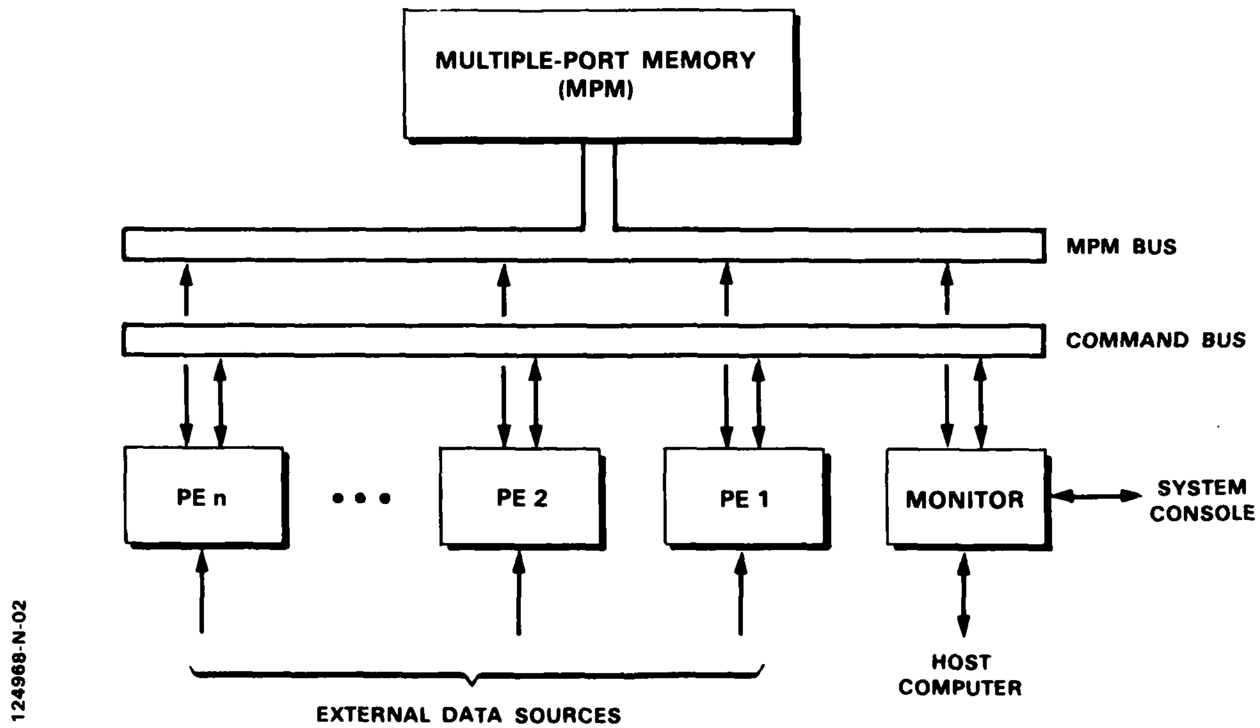

Figure II-3. DAA processor architecture.

The production of the 16 planned DAA boards has been completed. Testing and modifications of the Processor Element (PE) boards is continuing. Several enhancements to increase the speed and processing capabilities of the PEs have been designed. Two boards have been modified to include these changes and tested and sent to the Memphis test site. Several other boards have been modified and tested at the test box level and are ready for high level debug and system integration. Table II-1 shows the status and location of the PE boards. The revision numbers indicate the modification level to which the board has been tested.

TABLE II-1

DAA Processing Element Status on 30 June 1985

PE No.	Location	Revision	Status	Possible Problem(s)
1	Lincoln	Rev 3	Not Working	Local Memory
2	Lincoln	Rev 0	Working	
3	Lincoln	Rev 1	Working	
4	Lincoln	Rev 1	Working	
5	Lincoln	Rev 1	Not Working	DLOAD and LOC MEM
6	Lincoln	Rev 1	Working	* Drops Data
7	Memphis	Rev 3	Working	
8	Memphis	Rev 3	Working	
9	Lincoln	Rev 4	Not Working	ALU (Normalize)
10	Lincoln	Rev 4	Working	*Drops Data
11	Lincoln	Rev 4	Working	
12	Lincoln	Rev 4	Working	
13	Lincoln	Rev 4	Working	
14	Lincoln	Rev 4	Working	

A microprocessor-based test box has been built to allow low-level testing of the PEs prior to system integration. This low-level testing is indicated in the PE status table. Several modifications have been made to the test box to allow detailed testing of modules failing the more general diagnostics. High level testing of the boards that have passed the low level tests has required the continued development of DAA diagnostic programs. These include a recursive memory test, MPM diagnostics, and DAA command bus tests.

Software development for the DAA has centered around the components needed to support data collection operations. These components include the computation of weather parameter estimates from autocorrelation measurements and the resampling of polar data to a Cartesian grid. A signal processor simulator to provide simulated 'lags' data at real-time rates and a clutter mapping module also have been provided. Initial versions of these modules have been completed and tested successfully. Specific software modules include:

Software Module	**Purpose**
Lags to factors	Convert autocorrelation estimates to intermediate quantities, to be sent to the central computer for recording.
Factors to moments	Calculate final weather parameter estimates (reflectivity, velocity, spectrum width, S/N ratio).
Resampling	Resample polar tilt data to a Cartesian grid.
Control Processing	Collection and dissemination of control information, and generation of basic status display.

Clutter mapping minimizes the display of residual clutter. The data flow between these modules is shown in Figure II-4.

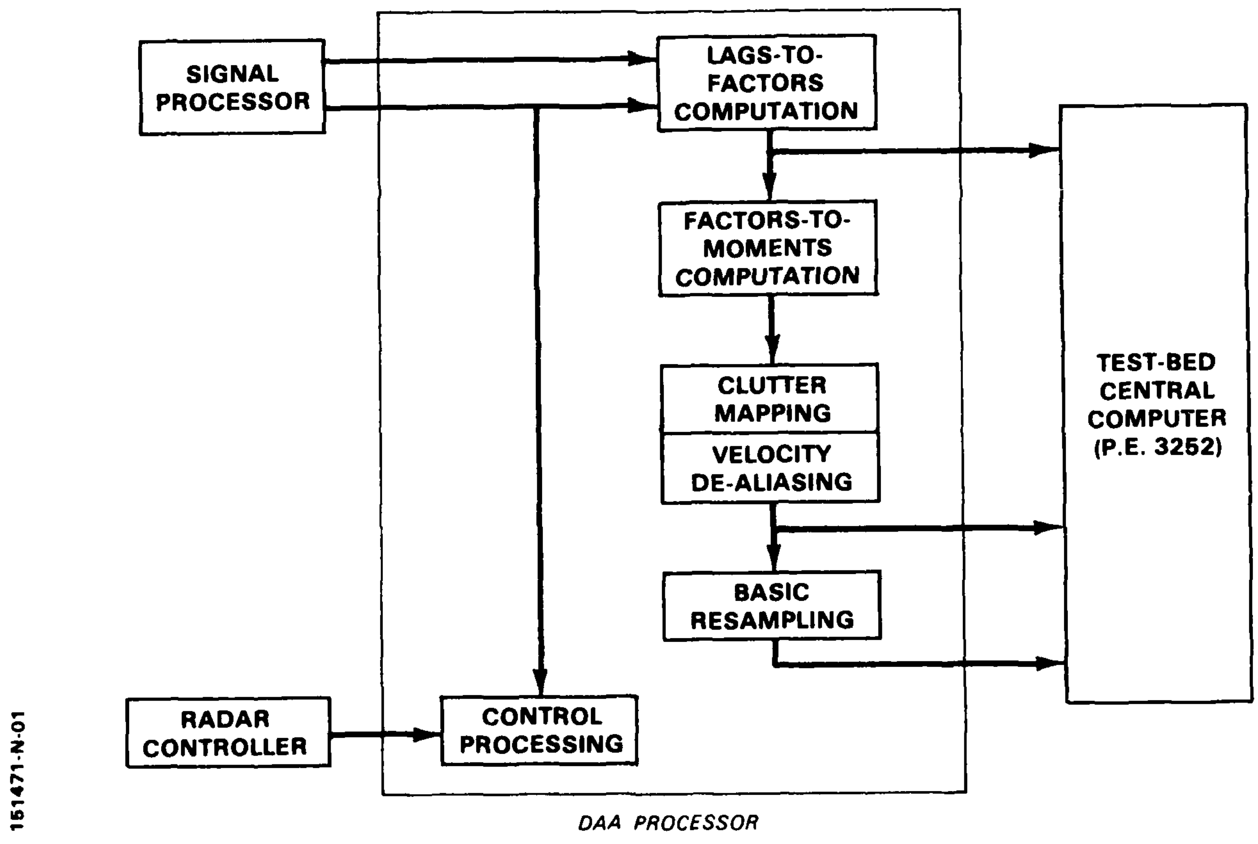

Figure II-4. DAA data flow for basic data processing.

A key accomplishment this quarter was integration of a signal processor simulator with the DAA. This simulator was developed to provide simulated 'lags' data to the DAA at real-time rates to support hardware and software testing at Lincoln in the absence of a working signal processor. This simulator is a hardware device consisting of enough random-access memory (RAM) to store 1000 sets of lags data. The output port of the simulator is compatible with the output port of the signal processor and interfaces directly to the DAA in the same manner as the signal processor. The input port of the simulator also interfaces to the DAA, and is used to load the simulator with test data. A software load routine is executed in the DAA to transfer the test data to the simulator before running real-time software.

In order to verify the results of the DAA lags to factors conversion software, a simulation program was written in FORTRAN to run on the Perkin-Elmer 3242. The input to this FORTRAN simulation program is the same file of simulated lags data that is downloaded to the signal processor simulator. After running both versions of the software, the output file generated by the lags to factors simulation is compared with the results of the actual DAA lags to factors software. This process has been performed using a number of different test cases to provide confidence that the DAA real-time software is operating correctly.

Enhancements have been made to the existing real-time program to read antenna position and time of day directly into the DAA rather than from the Perkin-Elmer 3210. This reduces the load on the Perkin-Elmer and reduces the time drift caused by generator power use. The control processing module for the next version of DAA software has been written and tested. This version handles CD beacon data as well as displaying the date, time, and antenna position on a small display. Also added is the ability to send header and control information to processing tasks in the DAA.

The final integration testing of the control processing software and the lags-to-factors modules in the test-bed system has begun. Some problems with communication between the DAA and the Perkin-Elmer 3250 have been observed. Several software modifications have been made to solve these problems, but additional testing is needed to determine if a communication problem still exists between the DAA and the host computer.

The initial resampling modules for both PPI and RHI scans have been completed and a successful front-to-end test has been performed with resulting resampled tilts displayed on a Genesco color display. Both the PPI and RHI modules have been integrated with the control module so that either PPI or RHI processing can be performed. This program transforms the radar data obtained on a spherical grid to a Cartesian grid one tilt at a time. The initial version includes several constraints to simplify the algorithm implementation. These constraints include a fixed 256×256 Cartesian output data space, fixed-radar position at the center of the Cartesian grid, and a Cartesian resolution sufficient to ensure that the maximum range radar data falls within the Cartesian data space. For RHI resampling, these constraints include a fixed 256×256 Cartesian grid and a fixed-radar position at the (0, 0) x, y Cartesian grid position.

Basic timing analysis of the PPI resampling code indicates a processing time of roughly 145 ms per radial (assuming data in each gate for all three products). Work is continuing on enhancements to make a more efficient version of the code to speed up the processing. Timing analysis for the RHI resampling is being initiated. A correction module to compute the earth's curvature has been integrated into the basic RHI resampling module as well as a beam filling module that calculates the number of subdivisions needed per gate to resample a tilt successfully. A FORTRAN program on the Perkin-Elmer has to be provided to allow flexible user control of the generation, download, and display of test data sequences and resulting resampled fields.

The DAA clutter mapping module that minimizes the display of residual clutter data has been completed and tested. Documentation of the clutter software module is proceeding.

G. RADAR/ANTENNA CONTROLLER

Control of the radar system, DAA, and signal processor by the Perkin-Elmer 3210 radar control computer has continued satisfactorily throughout this quarter. No significant changes or enhancements to the DAA and signal processor control were made in this quarter.

The principal objective of antenna control software development is to achieve a fast update for weather measurements despite the mount and servo limitations on peak acceleration and system bandwidth. The antenna control software for the Scientific Atlanta mount had to be completely redesigned to encompass new scan patterns as well as the changes in the dynamic response of the mount and the servo amplifier characteristics. This software development has required close interaction between the weather radar project software development personnel and the Lincoln Control Systems Engineering Group personnel who have designed and implemented the mount analog servo control system.

In order to provide a reasonable programming environment, the control program has been written in Ratfor, a preprocessor which translates a rational set of programming constructs into FORTRAN source code. While the particular Ratfor preprocessor chosen is neither the latest nor the most sophisticated version available, it is known to be bug-free and provides sufficient structure to do the job.

The work this quarter focused on writing, debugging, and running programs to print and plot pedestal control program log tapes, running step response tests using several sets of parameters in the algorithm to move the antenna to a designated position, and timing the TDR candidate PPI and RHI scans as well as recently developed NEXRAD scan sequences. Additionally, continuous azimuth rotation and faster sector scans were implemented, and the Sun pointing mode, used for system calibration, became fully operational.

Several modifications have been made to the version of the pedestal control program used operationally since December:

(1) Improved diagnostic information for post measurement analysis.

(2) The recently added Az and El tach outputs, providing direct angular rate data, are now recorded (but not yet used), and calibration 'constants' have been added for use with the tach outputs.

(3) Faster Sector Scans have been implemented by forcing all acceleration and deceleration to occur inside the weather measurement sector.

(4) Continuous Azimuth Rotation Scans (used for NEXRAD and 'on airport' TDR scanning) have been implemented.

Below we describe the principal accomlishments in each of these areas.

1. Improved Mount Diagnostic Data

The Control Systems Group personnel increased the servo system bandwidth to improve mount response. Several pedestal control test sessions were run remotely from Lexington, and log tapes and strip charts were made and shipped to Lexington for analysis. All requested printouts, and plots have been generated and given to the Control Systems Group personnel for analysis.

Additionally, each scan sequence 'request' from the Radar Control Program (which receives requests from the Perkin-Elmer 3250 computer) now is automatically tagged with the date and time at which the request is accepted by the Pedestal Control Program before being recorded on the log tape. This facilitates location of the appropriate data on the log tape when anomalous performance is encountered.

2. Angular Rate Data Usage

The pedestal angular velocity is used by the Pedestal Control Program both to determine when it is safe to switch from rate mode to position mode while either stopping or moving to a specified position and to determine the direction in which to move toward a specified azimuth.

Two 12-bit A/D channels have been added to the Radar Controller Interface to allow the software to determine the azimuth and elevation rates by measuring tachometer voltages (via the Radar Controller Interface) in lieu of the crude velocity estimates currently determined by dividing the change in position by the corresponding change in time. Currently, the raw azimuth and elevation tach readings are recorded on the log tape and a scale factor, an offset, and a noise floor have been provided for calibration of each tach.

Because the Pedestal Control Program sometimes will be used diagnostically when debugging the tach interface, the program may be prevented from using each tach for control purposes by zeroing the corresponding scale factor. When use of a tach is disabled, the program will revert to using the previously used crude velocity estimate for that axis.

A new software device driver for the Radar Controller Interface was required to enable the software to access the new tach status registers. This device driver now is used to access all status information in raw form. With the new driver, bad BCD digits in the azimuth and elevation position status now are detected whenever they occur. This problem previously was detectable by the program only when it was bad enough to cause position readings greater than 359.99 degrees.

3. Candidate RHI Scan Timing

The candidate RHI scan, used to determine whether the pedestal hardware and software are acceptable, consists of 13 elevation sector sweeps of 30 degrees at a speed of 15 deg/s with azimuth coverage of 18 degrees in 1.5 degree steps.

If the mount were limited only by peak accelerations of 15 deg/s^2 and a peak elevation velocity of 15 deg/s, this sequence could be done in 43 seconds. The current Lincoln specification requires that the sequence be done in not more than 47 seconds in order to be considered acceptable. The suggested times assume that all acceleration and deceleration take place within the scanned elevation sector and ignore the 'retrace' time between the end of the last tilt of one scan and the beginning of the first tilt of the next scai

The measured time of 40.77 seconds is below the minimum predicted time because the peak elevation acceleration is in excess of 15 deg/s^2.

4. Candidate PPI Scan Timing

The candidate PPI scan consists of nine azimuth sector sweeps of 120 degrees at various speeds and elevations: five 25 deg/s sweeps at elevation angles 15, 11.5, 9, 7, and 5 degrees; a 20 deg/s sweep at 3 degrees; two 15 deg/s sweeps at 2 degrees and 1 degree; and a 10 deg/s sweep at 0 degrees elevation.

This can be done in 77 seconds if the mount is limited only by peak accelerations of 15 deg/s^2 and must be done in not more than 84 seconds in order to be considered acceptable. The suggested times assume that all the acceleration and deceleration take place within the scanned azimuth sector and ignore the 'retrace' time between the end of the last tilt of one scan and the beginning of the first tilt of the next scan.

The measured time of 77.85 seconds is 1.1% above the acceleration limited time and well below the maximum acceptable time. The peak azimuth accelerations exceed 15 deg/s^2. However, the effective azimuth acceleration while slowing down toward the end of a sweep is dependent on the elevation position and the servo system bandwidth and varies between approximately 10 and 14 deg/s^2.

5. Candidate NEXRAD Scan Timing

Table II-2 shows two candidate NEXRAD (continuous azimuth rotation) scan sequences under consideration by the Federal Meteorological Handbook (FMH) committee E (see Section VI for a description of the committee's work). Measured times agree within 0.7% (worst case) with predicted times.

H. MAIN MINICOMPUTER

At this time, autocorrelation lags to moment conversion, recording of autocorrelation lags, and three-moment display generation is accomplished on a Perkin-Elmer 3252 superminicomputer.

TABLE II-2 Strawman NEXRAD Volume Scan Sequences					
Tilt Number	Elevation Degrees	Sweep Speed deg/s	Tilt Number	Elevation Degrees	Sweep Speed deg/s
1	0.4	14.3	1	0.4	14.3
2	1.2	"	2	1.2	"
3	2.2	"	3	2.2	"
4	3.2	14.8	4	3.2	14.8
5	4.2	15.1	5	4.3	15.1
6	5.3	15.3	6	5.4	15.0
7	6.4	15.1	7	6.5	15.3
8	7.5	15.3	8	7.8	"
9	0.6	25.6	9	9.1	24.0
10	8.6	"	10	10.5	"
11	9.8	"	11	12.1	"
12	11.0	"	12	13.8	"
13	12.3	"	13	15.8	"
14	13.6	"	14	18.0	"
15	15.1	"			
16	16.6	"			
17	18.2	"			
18	20.0	"			
Desired time = 350 s Measured time = 349 s			Desired time = 295 s Measured time = 295 s		

This computer has an auxiliary processing unit (APU) in addition to a CPU to permit concurrent processing of separate tasks. The current real-time system (RTS) uses only the 8 megabytes of random-access memory (RAM) to perform processing (as opposed, e.g., to use of a disk to store intermediate products).

A Winchester 400 MB disk was received during the period. This will be interfaced to the 3252 computer to replace the 86 MB disk that is being transferred to the 3210 radar control computer. This larger disk will permit fast retrieval of data sets for playback as well as better access for the next generation RTS.

The RTS software was enhanced to receive beacon reports from the Air Route Surveillance Radar and display selected aircraft positions on the three-moment displays. The RTS also was modified to display the trackball cursor's position with respect to the Memphis VORTAC. With these changes, the Olive Branch site was able to track and direct the University of North Dakota aircraft during missions from 21 May through 10 June.

During the quarter, work continued to modify the RTS to receive factors from the DAA. It is expected that significant time will be saved in the RTS processing when these changes are completed and integrated with the Version 2 DAA software. Progress in this area was slowed by the departure of a contract programmer in late May. A request for information (RFI) for a replacement programmer was issued to a variety of firms in June. Responses will be received in July.

I. FL-2 ENHANCEMENTS

The principal focus of test-bed enhancement activity was the procurement and preliminary software development for the Apollo work stations to be used as local and remote displays. Figure II-5 shows the various Apollo systems that were delivered at the end of June and the near term planned increments. Table II-3 summarizes the various Apollo component capabilities. The high resolution of the Apollo color displays will permit a 'pseudo-Advanced Automation System' display mode whereby a number of aircraft locations (with beacon ID and altitude codes) are displayed together with candidate ATC controller weather products. A sequence of lower resolution (e.g., 256×256) weather maps can be loaded into adjacent frame buffer locations to permit animation at rates up to 6 frames/s.

The current plan is to provide various graphical products (e.g., layered reflectivity and turbulence maps, low-altitude wind-shear regions and resampled tilt data) from the 3252 to an Apollo DSP-80 computation node via an Ethernet. The current plan is to use third party software from Internet Corporation to handle the 3252 Ethernet communications with Apollo providing the Apollo Ethernet communications board and software. Internet performed a partially successful demonstration of 3240 to Apollo transfer of files under the TCP/FTP protocol in late May. This protocol is not satisfactory for real-time communication between programs running on the two respective systems. After a series of discussions between Lincoln, Internet and Apollo personnel, it was agreed that TCP/IP 'sockets' used in the Unix 4.2 system represented the most attractive high-level communications format. Apollo agreed to furnish Lincoln a copy of their next generation operating system software that has user access to these routines.

A sole-source RFI will be issued to Internet in July to provide Perkin-Elmer TCP/IP 'socket' software as well as a fully responsive TCP capability. The code development validation testing will necessitate Lincoln shipping a work station to the Internet Florida plant for initial interface testing to be followed by an acceptance demonstration at Lincoln.

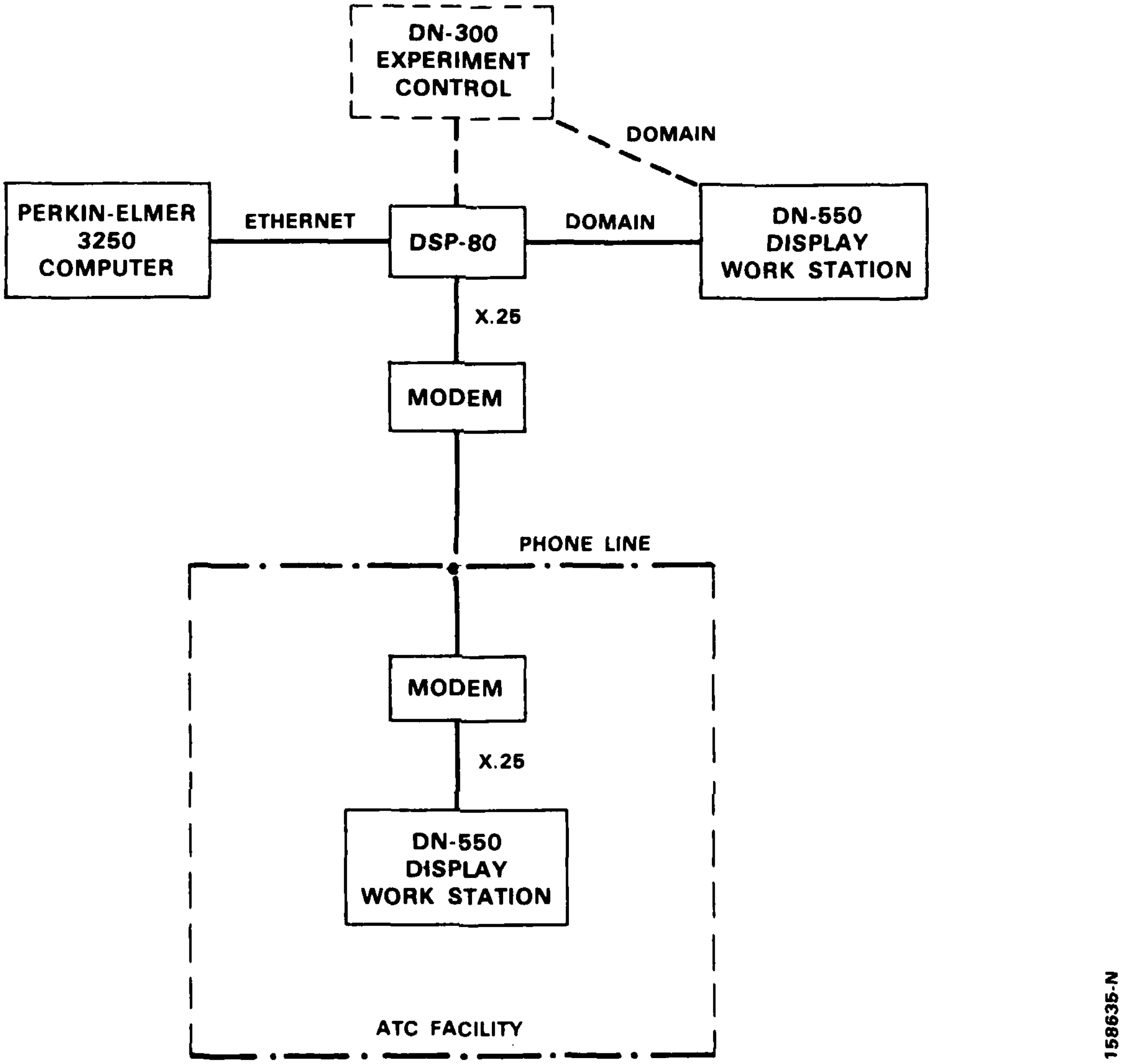

Figure II-5. Use of Apollo work stations in test-bed real-time system.

A delay of over one and one-half months occurred in the Apollo equipment delivery due to the Lincoln procurement process and delays by Apollo. We anticipate the various work stations becoming usable in July, but the schedule slippage makes it increasingly unlikely that a useful product demonstration can occur at the Memphis CWSU this calendar year.

The real-time control of the test-bed is severely limited in a number of areas. This has not prevented the recording of useful data thus far due to the slow scan rates necessitated by recording limitations. However, when the DAA lags to factors processing becomes operational, much faster scan sequences and scan sequence changes will become possible. Utilizing this

TABLE II-3

Test-Bed Apollo Work Station Elements

Apollo Unit Number	Display	CPU	Memory (MB)	Disk	Function (Tentative)
DSP-80	no	68010*	1.5	no	X.25 and Ethernet communications image compression
DN-550	color with 800 × 1024 pixels 256 colors 2 frame buffers	68010*	3.0	86 MB Winchester	remote and local weather products display control
DN-300	monochromatic bit mapped with 1024 × 800 pixels	68010*	1.0†	no	menu based control of test-bed operations (e.g., scan, PRF control)

* To be upgraded to 68020 processor.
† To be upgraded to 3.0 MB.

improved capability will require a much more 'user friendly' interface between the operation and the RTS. Perkin-Elmer does not provide the required interactive capability as a standard part of their software, nor is there any suitable third party software product.

The Apollo monochromatic work stations are widely used for user friendly interfacing to CAD CAM software due to their multiple window display capability and powerful local processor. We are investigating the use of third party menu generating software for Apollo work stations to develop a user friendly control of the overall real-time system. This control would permit menu window/mouse specification of various antenna scan, PRF, clutter suppression features, etc., as well as the consequences (e.g., anticipated volume scan time for a constructed antenna scan sequence) of a contemplated change in operating scenario.

We hope to have a demonstration of the third party menu generation software at Lincoln next quarter. If this is successful, we plan to purchase a monochromatic work station and the software this coming quarter so that the new user interface will be ready for the 1986 tests.

The data management and processing problems are associated with the large number (481 by the end of June) of weather data tapes produced by the system. Laser disk recording represents an attractive alternative owing to:

(1) the large storage capability (typically 1.2 gigabytes) for a single disk, and

(2) the small physical size of the medium (e.g., one could have a copy of all data sets at the site as well as at Lincoln).

The nonerasibility of the recorded disks is fully compatible with the archival nature of these data sets. Our initial assessment is that these drives are comparable in cost to a 6250 bpi tape drive. An RFI has been issued to a number of potential vendors. The responses will be evaluated in the next quarter and a purchase requisition issued if there is an attractive response.

III. SITE PLANNING AND OPERATION

A. MEMPHIS SITE

All of the principal FAA/Lincoln Laboratory Operational Wind-Shear (FLOWS) measurement systems operated this quarter as described below. The operations were under the control of Dr. R.E. Rinehart of Lincoln on the basis of weather forecasts furnished by UND personnel. Figure III-1 shows the current Memphis equipment locations.

1. Lincoln Radar Site

The FL-2 system is located on leased land at the Metro Industrial Park in Olive Branch, Mississippi. The site work was completed in February, and no Lincoln induced changes have occurred since that time. However, several new buildings were completed in the industrial park during the quarter and construction is commencing on another building. Portions of these buildings cause blockage of some coverage to the north of the site as well as spurious reflections of weather from other coverage regions. T. Fujita will take new panoramics of the site so that obstruction contaminated data can be edited in the post processing.

In 1984, progress was set back several months by lightning damage to the site. Considerable time and expense was incurred in improving the lightning protection during the period September 1984-February 1985.

The lightning protection so far has been successful. There have been two or three lightning strikes within about 1/4-mile of the site but no disruption of operations. Twice the lightning has caused the telephone bell in the operations room to ring once. Another strike early one morning caused sparks to come from one of the aircraft radios, according to the security guard on duty; no damage was done to any of the equipment, including the radio involved. Only time will tell if the protection is completely successful, but the indications to date are that it is working quite well.

2. University of North Dakota (UND) Site

The UND Enterprise C-band radar is located atop a Lincoln provided 50-foot tower on leased land in Hernando, Mississippi. This site became operational in April 1985. No site modifications were necessary this quarter. However, the current backup diesel generator cannot power both the electronics equipment and the air conditioner. If commercial power is lost during high temperature periods, it may be necessary to stop UND operations if the UND trailer internal temperature becomes too high.

3. Mesonet Sites

The thirty station mesonet network is located on various plots of leased land in Mississippi and Tennessee. None of the stations had to be moved during the period.

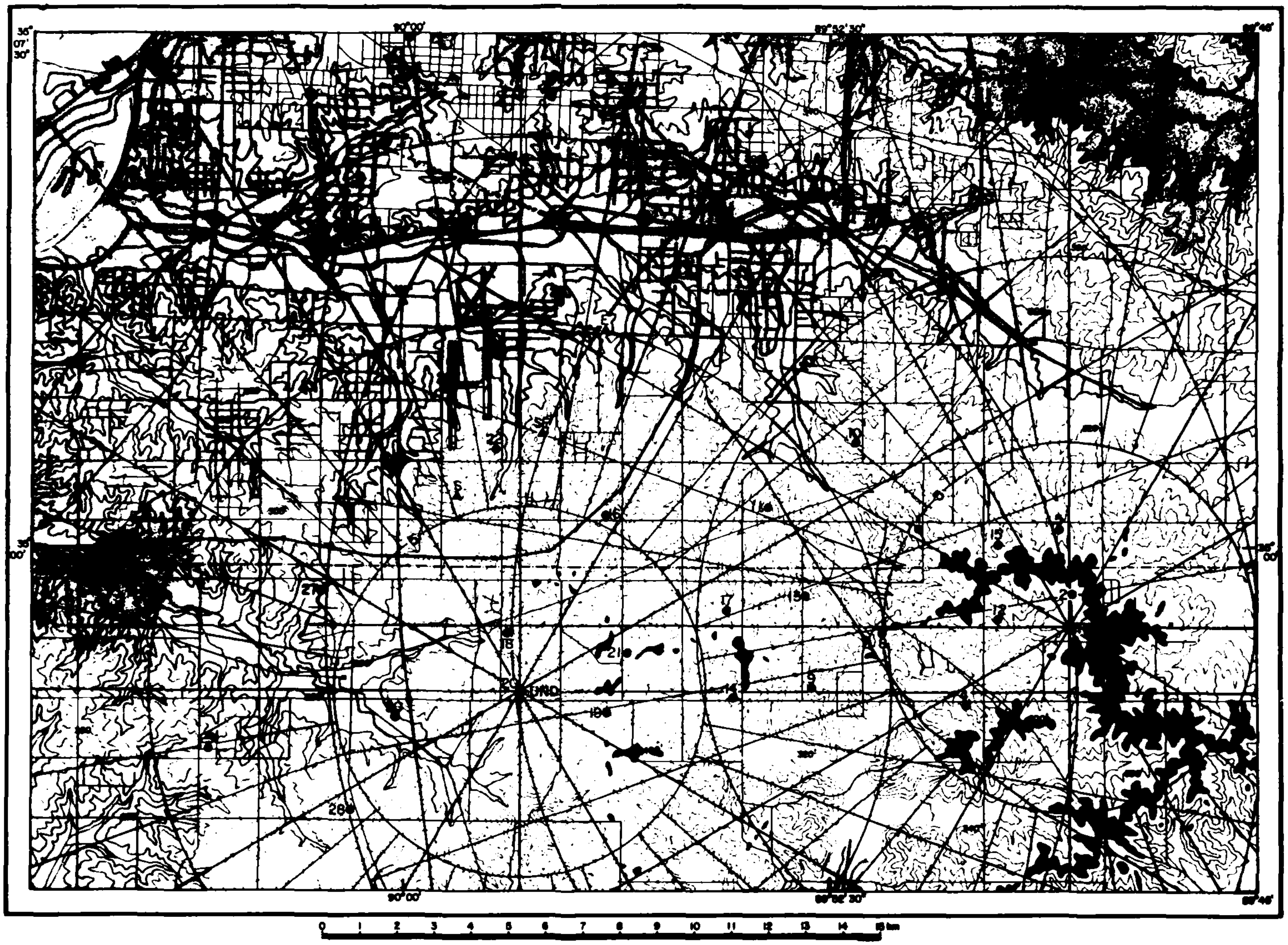

Figure III-1. FLOWS mesonet at Memphis.

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B. HUNTSVILLE SITE PLANNING

Huntsville, Alabama, has been chosen as the 1986 FLOWS experimental site. During the months of June and July (and possibly parts of May and August) 1986, the FLOWS effort will be joined by two other large data collection efforts in the Cooperative Huntsville Meteorological Experiment (COHMEX). The other projects are MIST (Microburst and Severe Thunderstorm Project), proposed and organized by T. Fujita and R. Wakimoto, and SPACE (Satellite, Precipitation, and Cloud Experiment) coordinated by J. Arnold at the NASA Marshall Space Flight Center. This mutual effort will provide a unique opportunity for Lincoln and the FAA to utilize multiple Doppler radars, several aircraft, special soundings, and surface data from close to 100 mesonet stations to help define the low-altitude wind shear characteristics in the southeastern portion of the United States as typified by Huntsville.

Planning for the Huntsville site began during the first week of this quarter with a site-selection trip to Huntsville by M.M. Wolfson of Lincoln, N.M. Fischer from the Lincoln Memphis site, and T. Fujita of the University of Chicago. Seven possible locations that were open and at high elevation relative to the surrounding land were selected and are shown in Figure III-2. Panoramic photographs were taken by T. Fujita at each site.

A trip was made by I.W. Copeland of Lincoln and N.M. Fischer at the end of April to locate landowners at sites No. 1 and No. 3. A number of contacts were made, and preliminary negotiations commenced for locating FL-2 at site No. 1 shown in Figure III-2.

In May, M.M. Wolfson attended the last afternoon meeting of a NASA Program Review at which the COHMEX field experiment status was summarized. She presented briefly the major components of the FLOWS project after J. Arnold of NASA had done the same for SPACE and T. Fujita for MIST. Several working group assignments then were suggested to handle overall COHMEX scientific coordination requirements.

During this same trip, contact was made with G. McCluskey of Huntsville, who agreed to serve as a local consultant for Lincoln for the radar and mesonet site selection and negotiation.

More detailed negotiations for site No. 1 were undertaken at a meeting with I.W. Copeland, G. McCluskey, and landowners in Huntsville at the end of this quarter. Two radars (both FL-2 and the new FL-3 ASR weather channel test-bed) will be located at site No. 1. Tentative agreement on availability and price were reached; final contractual negotiations will take place next quarter so that site preparation for FL-2 can commence as soon as possible.

C. MEMPHIS SITE OPERATIONS

1. FL-2 Measurements

The FL-2 radar was fully operational throughout the quarter. We collected a total of 434 data tapes during 39 operational periods on 31 days, for a total of about 151 h, 35 min, of data. Operations were conducted at least once during every hour of the day, but the busiest time was generally between noon and 2100 CDT (1600 and 1700 CDT were the two peak hours). The

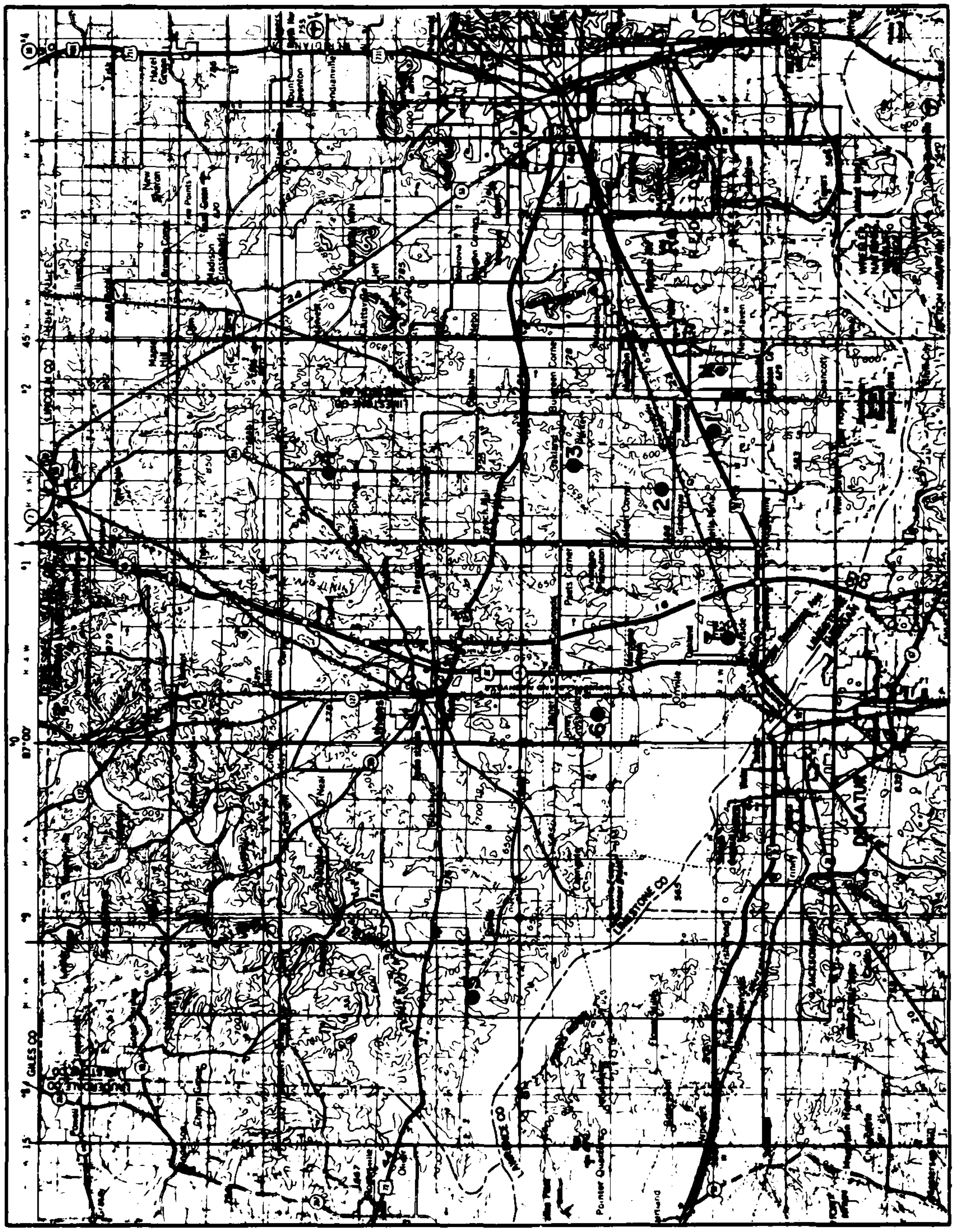

Figure III-2. Potential test-bed radar sites near Huntsville, Alabama.

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average operational day had 5 h, 28 min, of data collection. Figure III-3 shows the number of times during each hour of the day that operations were conducted.

The beginning of the period was characterized by prefrontal, frontal, and postfrontal lines of thunderstorms much of the time, while the last part of the period was characterized more by widely scattered, air mass thundershowers.

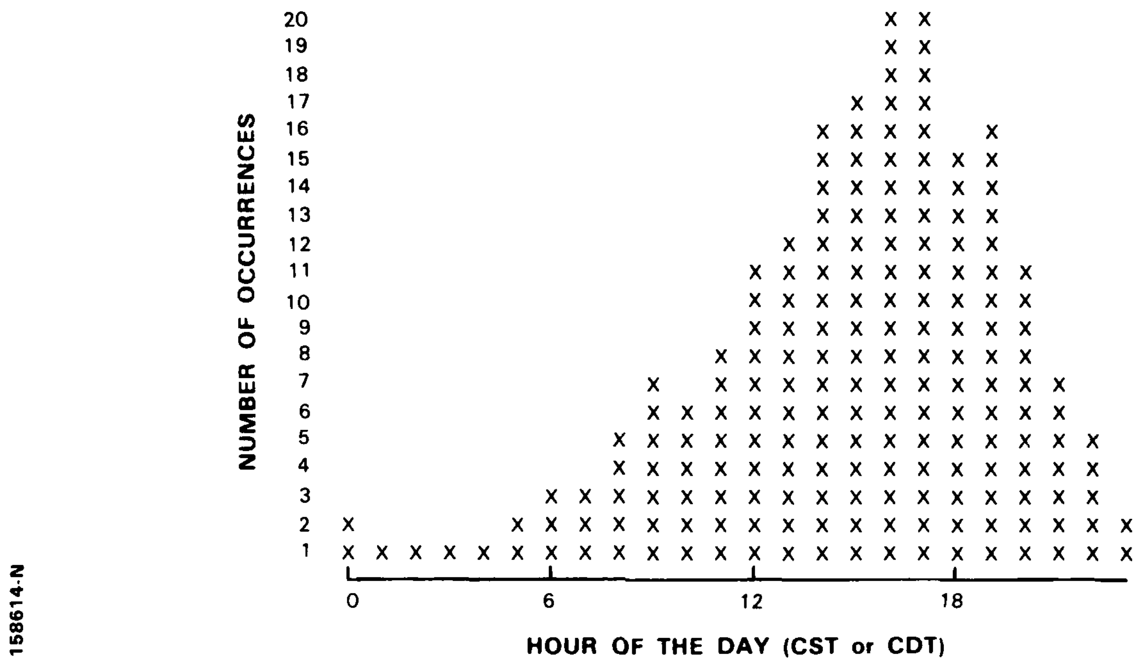

Figure III-3. FL-2 radar operation times during April-June 1985.

Numerous gust fronts were observed throughout the quarter and many microbursts during the last half of the period. In June alone, there were more than 30 microbursts noted in the radar log. Tables III-1 to III-3 summarize the radar log results, while Figure III-4 shows the frequency of low altitude wind-shear (LAWS) events observed at the site. During the period from 20 May to 10 June, LAWS events generally would not have been noted in the real-time log since the real-time displays were focusing on the weather characteristics aloft where the UND aircraft was flying.

While many of these were well away from the mesonet, others should have been close enough to provide quite useful data on their intensities, durations, and life cycles. Dual-Doppler data were collected on many of these microbursts.

The last half of June was particularly rich in microburst activity. Between 24 and 27 June, we saw microbursts every day and noted a total of nine in the radar log. Most of these also put out gust fronts that sometimes outlasted the storms spawning them. Some of the gust fronts were

TABLE III-1

Test-Bed Operations in April 1985

Date 1985	Day	Tape No.	Oper Hrs.	Weather Conditions
1	M			
2	T	47 (Clut)		
3	W			
4	T			Windy (51 mi/h) at site
5	F	48-60	1024 -1336	Long line of TRWs w/cold front, 25 m/s in mesonet 62/69 0.02
6	S			47/m mostly clear
7	S			36/60 over weekend
8	M	61 (Clut)		
9	T			36/66 Clear in a.m.
10	W			40/74 Ci/Ac
11	T			42/74 0.04 in Ovcst
12	F			47/80 Ac/As BINOVC
13	S			56/83 Ac, ptly cldy
14	S	62-74	0540 -1228	Weak cold front, slow little winds
15	M	75-91	0615	52/73 0.06 in, Weak post-front
16	T			48/76 Foggy/hazy a.m., clear
17	W			52/88 Clear
18	T	92 (Clear air)		Dual-Doppler, 60/87
19	F			60/87 Clear, no storms
20	S			61/87 Clear a.m.
21	S			63/86 Ptly cldy p.m.
22	M	93-103	2002 -2400	63/86 Prefrontal line
23	T	104-125	1419 -1946	a.m. line of TRWs; p.m.: line of TRWs; hail, windy; winds above >55 mps for >2 s
24	W			Clear
25	T			52/84 Clear
26	F			66/80 0.04 in RW a.m., 60 dBz
27	S	126-144	0900 -1540	m/86 0.46 in, Lines of prefrontal showers; gust front or converg. line; rapid clearing after storm
28	S			m/86 Cloudy and hot
29	M			61; Foggy/hazy a.m. ptly cldy
30	T	145-180	1330-0108	Precold front, hail, tornado (ARK), GF MB, nearby lightning, 68 mi/h winds at MEM airport

Abbreviations:
Ac = Altocumulus
ARK = Arkansas
BINOVC = breaks in overcast
Ci = cirrus
Cldy = cloudy
Clut = clutter tape
Converg. = convergence
GF = gust front
MB = microburst
m = missing temperature
MEM = Memphis
Ovcst = overcast
Ptly = partly
RW = rain shower
TRW = thunderstorm
w/ = with
x/y = high and low temperature (in degrees Farenheit)
> = greater than
u.vw = u. vw inches rain

TABLE III-2

Test-Bed Operations in May 1985

Date	Day	Times	Tapes	Weather
1	W	1300-1714	181-197	Cold front, tornado
2	T			Overcast, drizzle
3	F			Clear, high press.
4	S			Clear, high press.
5	S			Clear, high press.
6	M			Clear, st. front N
7	T	1945-2145	199-206	St. front, TRWs,
8	W			a.m. ovcst, drizzle rotation
9	T			Ovcst, low clouds
10	F			Ovcst
11	S			Ci ovcst, RW p.m.
12	S			Mostly clear
13	M	1927-2117	208-213	Prefrontal TRW line
14	T	1205-1805	217-232	Prefrontal TRW line, rotation, little wind
15	W			Clear behind front
16	T			Mostly clear, high pressure, windy
17	F			Mostly overcast, low clouds

Date	Day	Times	Tapes	Weather
18	S			Clear, high pressure
19	S			Clear, high pressure
20	M			Clear a.m., ptly cldy
21*	T	1412-2012	233-255	Line TRWs p.m.
22	W			Low aloft, ovcst, light rain
23	T			Clear, high pressure
24	F			Clear, high pressure
25	S			Clear, high pressure
26	S			Mostly clear
27	M			Ci overcast, Ac
28†	T	1549-2208	256-276	Prefrontal TRW line, GF, rotation, pressure event
29*	W	1928-2229	277-284	MCC line of TRWs, warm/dry GF
30	T			Partly cloudy
31	F	2118-2201	285	Mostly cloudy, small RWs late afternoon

* One flight by UND aircraft.

† Two flights by UND aircraft.

TABLE III-3

Test-Bed Operations in June 1985

Date	Day	Times	Tapes	Weather	Date	Day	Times	Tapes	Weather
1	S			Mostly clear	18	T	0218-0454	383-392	Early a.m. TRWs; p.m. clearing
2	S			Mostly clear, stationary front N	19	W	1719-1900	394-395	Mostly clear, high pressure, couple RWs
3	M			Mostly clear	20	T			High pressure, mostly clear
4*	T	1355-1628	289-291	Mostly clear, storms 120† km away	21	F			Partly cloudy; p.m. showers E and S
5†	W	1524-1950	292-297	St. front N, high press. S; golfball hail; cloud thin-line echo	22	S	0838-1229 1455-1707	396-408	Prefrontal squall lines, rotation, windy
6‡	T	0943-1202 1612-2036	298-310	St. front overhead, lines of TRWs, N1 penetrated GF	23	S	1624-1912	409-413	Generally fair, scat. TRWs, thin-line echoes (convergence lines?)
7*	F	1126-1459 1623-1705	311-320	Cold front passage, prefrontal squall line, MB GF funnel cloud	24	M	1301-1842	414-427	Bermuda high SE; scat. TRWs; ring GFs, 3 MB, rotation
8	S			Mostly clr, high press.	25	T	1209-2005	428-448	Bermuda high, scat. TRWs; ring GFs, 4 MB wind shear layer near sfc.; explosive cloud growth midafternoon
9	S			Mostly clr, high press.					
10*	M	1329-1942	321-340	Cold front aloft, lines of TRWs became general rain, 4 MB, GF, hail					
11	T	0544-0803	341-360	Cold front N; a.m. TRWs, line of TRWs p.m., GF	26	W	1246-1742	449-460	Bermuda high, scat. TRWs; 3 MB, ring GF, tree damage from Hickory Ridge MB
12	W			Dry, clear behind cold front					
13	T			Clear, highest pressure in 8 weeks	27	T	0955-1205	461-476	a.m. air-mass TRWs; cold front p.m., 5 MB, GFs, clear air layers
14	F			Clear, high pressure	28	F			Generally cloudy behind cold front
15	S			Mostly clear, high pressure, TRWs E and N	29	S			Clear, cool, high pressure
16	S			Mostly clear, high pressure	30	S	1644-1858	477-481	Fair a.m.; scattered TRWs, MB, GF, rotation
17	M	1139-1444 1737-2052	362-382	Precold frontal TRW lines (old MCC), GF, rotation; p.m. lines of TRWs, MB, 50 mi/h winds, rotation					

* One flight by UND aircraft.

† Two flights by UND aircraft.

‡ Three flights by UND aircraft.

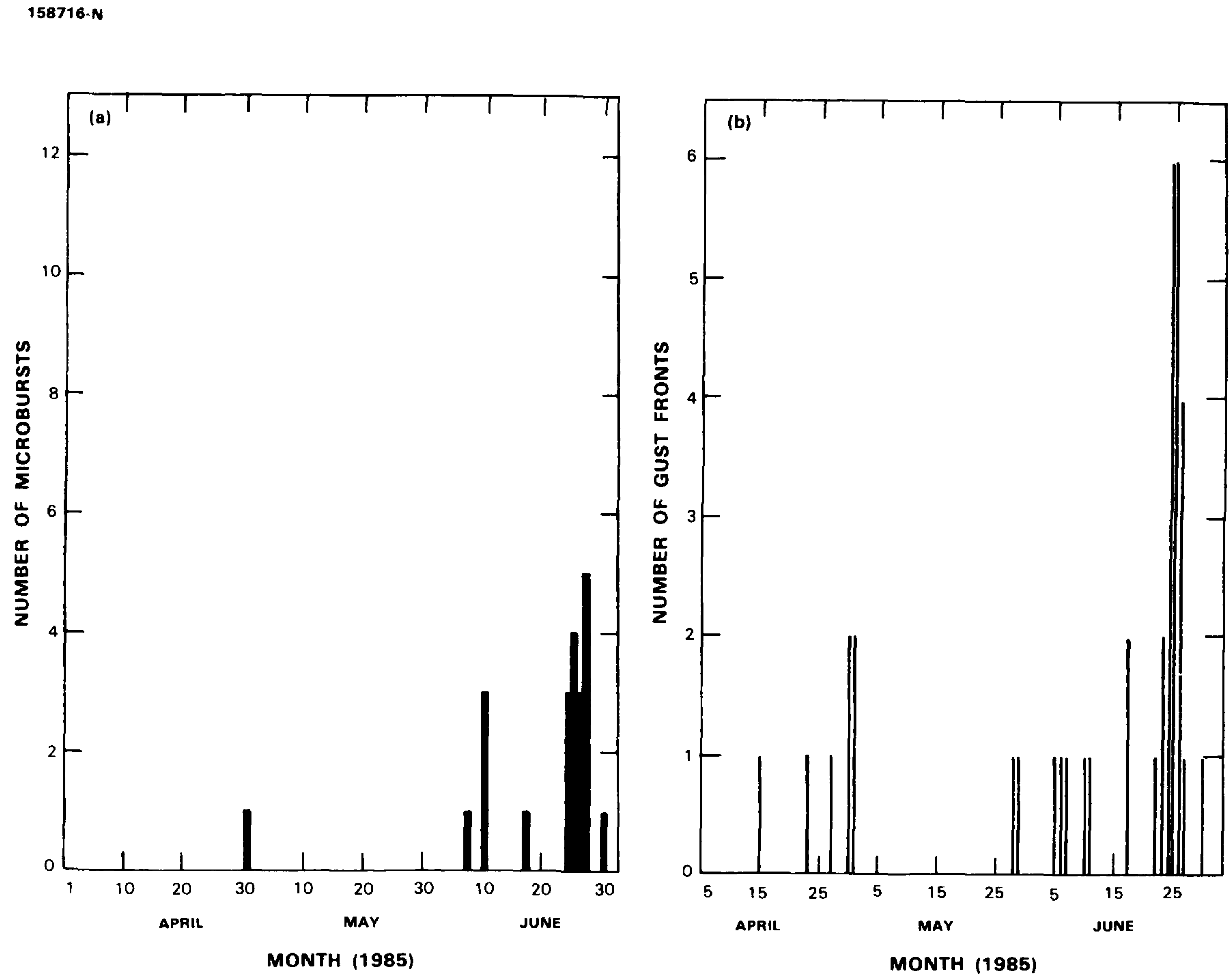

Figure III-4. Number of (a) microbursts and (b) gust fronts per day for April-June 1985 recorded in the FL-2 radar log at Olive Branch, Mississippi.

ring-like, expanding radially outward with time. The only unfortunate aspect of these microbursts is that most occurred outside (sometimes moderately far away from) the mesonet. At least one of these storms was moderately well covered with dual-Doppler radar scans for much of its active life.

2. Mesonet Operations

Lincoln has been operating a 30-station mesonet in the Memphis area since early 1984. The individual stations (obtained originally from the Bureau of Reclamation and substantially upgraded by Lincoln) record a 1-min average of temperature, pressure, humidity, winds, and precipitation. The results from the past half hour are telemetered to a GOES satellite every 30 min and then transmitted down to the Synergetics Corporation ground station. Lincoln receives a data tape from Synergetics weekly with the data for the various stations.

The mesonet operated reasonably well throughout the quarter. There were a number of minor problems at various stations during this time as well as a prolonged period of problems with station 9. The problem with station 9 turned out to be a bad cell or other internal problem with its battery; once the battery was replaced, it resumed normal operations.

Among the miscellaneous problems encountered were sensors going bad (relative humidity, two wind speed sensors had O-rings break), slight drifting of frequency, clock oscillator burning, bus hanging up on one DCP, and nearby lightning producing problems at one station.

Early in the quarter, we changed the intercept values in the calibration equations for the pressure sensors to eliminate the 19.1-Mb average error in pressure from all stations in the mesonet. Pressures reported by the stations now average approximately correct sea-level pressures, but they still exhibit individual errors due to temperature effects and errors in the slopes of the pressure calibration equations.

One further type of pressure fluctuation was discovered in the pressure data. This is that some stations report pressures that change by 1 to 3 Mb between consecutive minutes. These changes seem somewhat random in nature. The overall pressure trend is still detectable, but some temporal filtering (up to 30 min for some stations) would be required to reduce fluctuations to an acceptable level.

Lightning protection was added to all the sensor inputs on each of the mesonet stations. This required soldering a gas discharge diode to each input terminal on the boards connecting sensors to the DCPs.

3. LLWSAS Recording System

Lincoln has been recording the Memphis International Airport Low Level Wind-Shear Alert System (LLWSAS) data continuously since the summer of 1984 on a Lincoln developed recording system. Weekly the site personnel go to the Memphis tower to change data tapes. The LLWSAS recording system worked reliably throughout the quarter.

4. University of North Dakota (UND) Radar Operations

The UND operates a C-band Enterprise radar with a 1.5° beamwidth antenna and Sigmet Corporation signal processor approximately five miles to the south of the Memphis Airport. The UND radar commenced operations 1 April and continued operations throughout the periods that the FL-2 site operated. A total of 198 tapes were recorded by UND during this period.

Coordination of scanning between the FL-2 and UND sites is accomplished by radio with a telephone available as a backup. The data tapes from the UND measurements are copied on the FL-2 site Perkin-Elmer computers. The original tapes are sent to UND and the copies to Lincoln for subsequent analysis.

5. Aircraft Support

a. UND Citation

The UND Citation aircraft (NEXRAD1) arrived in Memphis 20 May 1985 to commence measurements. This aircraft is equipped with:

(1) a fairly comprehensive meteorological sensing package (temperature, dew point, liquid water content, radiometers, cloud droplet spectrum, ice crystal and water drop measurements, icing rate, and cloud photographs),

(2) turbulence sensing equipment (INS, three-axis accelerometer and differential pitot tube), and

(3) automatic cameras on both sides of the aircraft.

Real-time control of the aircraft during experiments is accomplished by VHF radio discussion between the FL-2 site personnel observing real-time displays (with the aircraft position shown as an overlay to turbulence and reflectivity maps) and UND personnel aboard the aircraft. The aircraft data tapes are being checked and copied at UND and then shipped to Lincoln for subsequent analysis.

A number of minor problems were encountered in the UND aircraft operation:

(1) The main pressure sensor went out for a day or more at one time, and the onboard computer crashed a number of times on one flight.

(2) Communications between the aircraft and the Lincoln Laboratory field site were occasionally poor. When the aircraft got too far from the radar, too low, or was in icing conditions, we were unable to communicate for periods up to 15 min or more.

(3) There were two problems related to air traffic control. One was that one storm we were working required traveling back and forth between two air sectors, causing problems at the air traffic control center; we switched to another storm of similar characteristics with no significant change in data

quality. Second, on the very last flight of the period, the aircraft took off just before the afternoon rush at the Memphis Airport. Unfortunately, incoming and outgoing traffic and the storms in the vicinity made it necessary for the center to put the aircraft into several straight line holding patterns outside of the storm area. It was just about 2 hrs between the time the aircraft took off and the time they finally got to collect their first data.

Not withstanding these problems, useful data was obtained on a number of flights as summarized in Table III-4.

TABLE III-4

UND Citation Flights During May-June 1985

Date	Time (CDT)		Flight Duration (hr:min)	No. Tapes Collected	Events
	Take off	Landing			
21 May	1620	1806	1:46	9	Test Flight, Turbulence, Sounding
28 May	1604	1920	3:16	8	Turbulence
	2051	2158	1:07	3	Turbulent Layer (Windshear)
29 May	1931	2157	2:26	9	Penetrated Gust Front
4 June	1502	1629	1:27	2	'Moderate' Turbulence
5 June	1550	1940	3:50	8	'Wild Ride', Hail Storm, Sounding
6 June	1016	1214	1:58	12	'Light', 'Moderate' Turbulence
	1705	1822	1:17	3	Gust Front
	1907	2035	1:28	3	Turbulence
10 June	1404	1708	3:04	3	Traffic Delay, Multiple Approaches

b. Technical Center Aircraft

A letter was written to personnel at the FAA Technical Center recommending modifications and additions in their Convair 580 instrument package that would help achieve the best possible experimental results during the FLOWS coordinated aircraft-Doppler radar turbulence measurement studies. It is anticipated that the aircraft will be available during the month of October 1985 when frontal storms of near-springtime intensity often are experienced in the Memphis, Tennessee, area.

Specifically, it was recommended that a flow angle sensor, a three-axis rate sensor, two horizontal accelerometers (one for each orthogonal axis), and a dew point sensor be added to the current complement of sensors (see Table III-5). The Litton 51 INS currently on the aircraft will continue to be used. All other instrumentation recommended is being added by the Technical Center with the possible exception of the three-axis rate sensor that may be purchased by Lincoln.

current complement of sensors (see Table III-5). The Litton 51 INS currently on the aircraft will continue to be used. All other instrumentation recommended is being added by the Technical Center with the possible exception of the three-axis rate sensor that may be purchased by Lincoln.

TABLE III-5

Existing Sensors On Board the FAATC CV-580 Aircraft

Sensor	Outputs	Resolution
Litton 51 INS	Latitude	0.1 min
	Longitude	0.1 min
	Track Angle	0.1 deg
	True Heading	0.1 deg
	Roll Angle	0.1 deg
	Pitch Angle	0.1 deg
Pitot Tubes	Bar Altitude	0.003 psia
	Stag.-Stat. Press.	0.003 psid
Setra Accelerometer	Vertical Acceleration	0.001 G
Rosemount Temp. Probe	Total Temperature	0.1°C

6. Additional Weather Data

The NWS daily weather maps and GOES satellite image are received and archived daily at the site. Additionally, the UND radar site personnel are preparing a detailed meteorological summary for each day on which operations are conducted.

7. Additional Clutter Data

During 1984, additional on- and off-airport clutter measurements in support of the weather radar program were accomplished by the Lincoln Air Vehicle Survivability Evaluation (AVSE) program personnel. The AVSE measurement van was not available this quarter to make similar measurements at other potential weather radar sites.

IV. EXPERIMENTAL DATA REDUCTION AND ALGORITHM DEVELOPMENT

A. PERKIN-ELMER COMPUTER SYSTEMS

Both Perkin-Elmer 3240 computer systems used for data analysis (Figure IV-1) experienced heavy use during this quarter. While the machines exhibited symptoms of overloading on occasion, hardware problems were not a limiting factor. Perkin Elmer maintenance has continued to exhibit an increasing interest in keeping our systems up and running.

Two new 474-megabyte Fujitsu Winchester-type disk drives have been installed, one in each system. One system has had the new disk fully incorporated; it is partitioned into two large volumes, one for data files, and one for source files. On that system, the two source file disk volumes have been incorporated into a single volume to reduce confusion. Furthermore, separate volumes for spool and temporary file, and a volume for use by the Virtual Task Management (VTM) (quasi-virtual memory system) have been provided. Finally, this system now will have an 80-megabyte removable disk pack available for general use. It is expected that the second Perkin-Elmer 3240 system will have been altered to match these changes, with the exception of the removable disk pack, by the end of the first week of the next quarter.

A system to allow multiple-user access to the Versatec V-80 electrostatic plotter has been devised and implemented. It is now possible for users to send NCAR metacode graphics to be plotted in batch mode, as easily as it is possible to have a file printed. The one remaining problem is the fact that the Versatec driver provided with our hardware may not be appropriate for (our current) system revision 7.2 during otherwise routine plotting operations. It has been observed that intermittent I/O faults occur such that the system will 'hang' for long periods of time (over 30 seconds) while the driver software tries to resolve these faults. The Versatec software consultant claims that the new OS 7.2 compatible driver, which is about to be distributed, will solve this problem. Until then, users are being discouraged from Versatec plotting operations during daytime operations.

In the software area, an evaluation is under way of Perkin-Elmer's 'Universal optimizing' Z compiler. The LAYER program has been selected as representative of the type of program that should be likely to benefit from this compiler, which is capable of compiling subroutines in-line, thus avoiding the overhead of subroutine calls. The local Perkin-Elmer office has offered to provide compilations of our code so that we might evaluate performance improvements, if any. After initial difficulties in getting the in-line directives to have the desired effect, it appeared that a successful compilation was achieved. On initial testing, the resulting task seemed to perform correctly, with a 40 percent reduction in CPU time. However, testing is not complete, and there are some indications of anomalous errors occurring under certain circumstances.

In a related vein, evaluation of the Perkin-Elmer Virtual Task Management system is under way. VTM allows automatic paging of memory to disk, thus allowing the execution of very large memory-intensive tasks without monopolizing the limited resources of the computer. This system

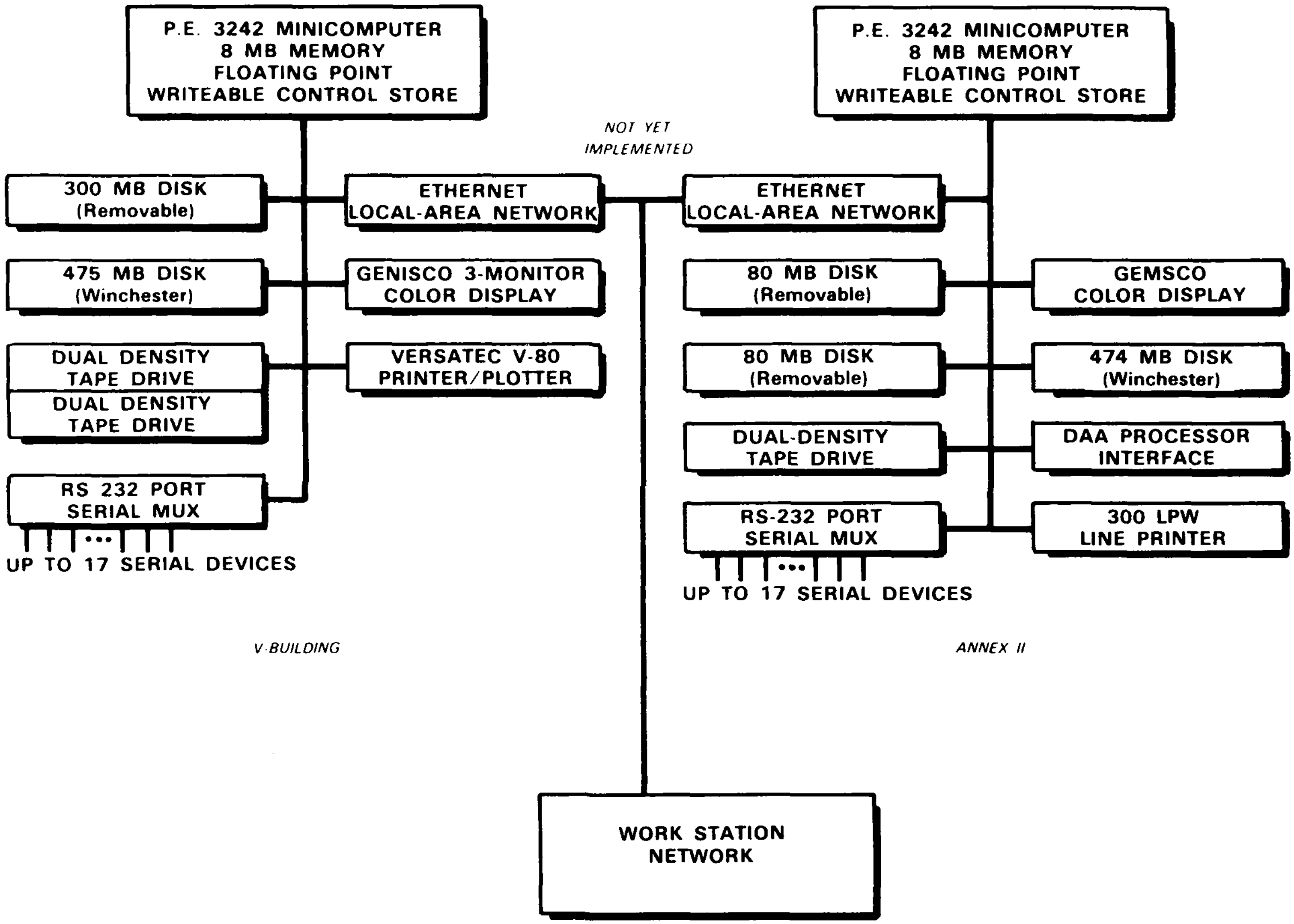

Figure IV-1. Block diagram of Data Analysis Facility.

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seems very promising, and the time penalty is ordinarily not very large. It will become an integral part of layering and resampling tasks in the near future, since there are so many users beginning to perform these basic functions concurrently. There are many memory-intensive tasks that may benefit, and guidelines for the use of VTM currently are being drawn up.

Due to the increasingly large amount of data processing required, a third operator has been hired for the second shift. This addition to the computer operators staff allows us to operate the machines 24 hours per day, at least 5 days per week, a prerequisite for completing the data reduction necessary.

The load will continue to increase in the future, such that the Perkin-Elmer machines will be saturated. In the next quarter, we will investigate options for substantially increasing the data analysis computation capability.

B. RADAR DATA ANALYSIS SOFTWARE DEVELOPMENT

The Lincoln radar data analysis software development effort centers around a compact, highly versatile common format for radar data (CFT) and an equally versatile format for use with data that is described naturally in a Cartesian coordinate system (CAR). A series of translators allow conversion of radar data obtained in a variety of formats into CFT; then all the utilities and analysis programs developed to date can be used to study that data. This philosophy allows us to accept data in any new format with little extra effort, and ensures that the further development of any common format utilities widely benefits the entire project.

Progress this quarter on radar data analysis software development was focused in four general categories: translators to produce Common Format (CF) radar data tapes, utilities to allow analysis of CFT data including work on the multiple Doppler analysis program, graphics capabilities for display of the analyses, and continued software maintenance.

1. Translators

Testing of the new translator from Universal (Common Radar Data Exchange Format) to CFT continued early in the quarter. It has been enhanced to allow default of user-specified header variables, such as the radar location or the receiver noise level, that may have been omitted or written incorrectly on the Universal tape.

A translator to convert an older Lincoln internal common format into CFT was written and released this quarter. This program will be used to translate five data sets for which preliminary storm tracking results are available.

Design and implementation of the translator from FL-2 real-time recording format to CFT were completed, with testing scheduled for completion in the early part of the next quarter. In the process of developing this translator, the CFT write package was enhanced to allow comments to be written at any time during the processing of a volume scan, since this is how they appear on the raw FL-2 format tapes. A prioritized list of cases to be translated has been compiled based on radar operators' logs written during data recording.

Considerable effort was devoted towards validation of the University of North Dakota (UND) translator from their raw recording format to Universal. This involved moving the UND code to our computer, and attempting to translate a raw UND tape. After making modifications to get the code to run, some scans were translated into Universal, and it was found that the data values were scaled incorrectly. A new version of the code corrected this problem, but it appears that some important information (e.g., pulse repetition time) is missing from the header. More important, the translator apparently does not provide true scans; each file (scan) on the output tape appears to contain a series of scans strung together. Personnel at UND were notified of these problems, and a new version of the translator is being written at UND.

Once the UND to Universal translator has been validated, UND raw data will be translated first to Universal and then to CFT for further analysis. We will review at that time the possibility of developing our own translator to go directly from the raw UND format to CFT.

2. Utilities

A new version of the RESAMP program, which resamples tilts into Cartesian fields, was written and released this quarter. This version includes a more generalized and user-friendly command interface and takes advantage of the recent capabilities added to the CFT and the CAR data formats to allow product specification by name.

The new version of LAYER, which resamples tilts into constant altitude layers with selectable thickness, was completed. Changes include a more generalized and friendly user interface, the ability to threshold on signal-to-noise ratio, radial clipping in azimuth and altitude, and the ability to work with RHI as well as PPI data.

Enhancements to the BSCAN program, which prints out radial data in range-vs-azimuth tabular format, are being made mainly to speed execution time. A new scheme for using temporary files and a new output format have been specified.

Work also began this quarter on implementation of the NCAR/NSSL multiple Doppler analysis program, used to derive the three-dimensional wind field from Doppler velocities from two or more radars. Three-dimensional wind fields are useful both for understanding the physical mechanisms generating LAWS events and for studying the effects of antenna siting/geometry on the detection of such events. Essentially the entire program is being rewritten and tested. Separate unrelated operations all included in the original program are being made into separate programs: layering, three-dimensional wind synthesis, and global variational analysis. The CAR format will be used for the intermediate format between layering and three-dimensional wind synthesis operations and for the final output wind data. CFT format will be used as input to the layering operation, which now includes the Cressman interpolation technique used in the original code. Computer memory limitations have been a major consideration in rewriting the wind synthesis program.

3. Graphics

A graphics package (CARGRAF) has been developed that will draw contours or wind vectors for data stored in the CAR format. This program makes use of the NCAR graphics software and has a full compliment of user-controllable options. These options, such as titles, scaling, and tick mark labeling are all command controlled so that no user programming is required. The output of this graphics package is an NCAR metacode file that can be plotted on any graphics device for which a translator has been written. Metacode translators are available for both the Tektronix 4015 terminal and the Versatec V80 electrostatic plotter.

4. Software Maintenance

As applications that make use of previously developed radar data analysis software increase, some problems inevitably are uncovered that thorough testing did not reveal. This quarter, errors were found in the CFT read and write packages related to the use of user-defined products. These problems did not appear when standard CFT products were used.

Also, the Universal to CFT translator is being reorganized to ease the maintenance of that code, and a problem with accessing incorrectly written Universal types (two EOF marks between scans instead of one) was fixed.

C. MESONET/LLWSAS DATA ANALYSIS

The wind data, continuously collected by the mesonet and LLWSAS networks, will be compared with Doppler radar data collected during thunderstorms. The results will be used to confirm low altitude wind shear (LAWS) and other possibly hazardous weather events detected by the radar and to provide an indication of undetected wind shear events. The additional meteorological data collected by the network will be used to diagnose the relationship between the temperature, pressure, relative humidity, rainfall, and winds during these events and thus to gain a better understanding of the causes and circumstances of low altitude wind shear.

A software package consisting of many different programs to process and analyze mesonet and LLWSAS data has been designed and largely implemented. The data from both the mesonet (30 stations) and LLWSAS (6 stations) is translated into our Lincoln Laboratory Common Instrument Data Format (CIDF), and all other programs allow us to confine the input format for analysis programs to CIDF and thus to be able to accept data in any new format with little extra effort.

During this second quarter of 1985, all software needed to edit and calibrate the mesonet and LLWSAS data was completed, as was the software to search for wind shear events and display them. The complete 1984 dataset (212 days, 2 May-30 November) was processed. After only the data from May had been checked for microbursts and over 900 were found, the detection algorithm was modified. The May data was rerun with the other six months of data.

The new algorithm detected 3210 wind-shear events as microbursts. For each of these, a synoptic plot of the winds at all the stations (Figure IV-2) and a 15-min time series plot of all the variables at the station with the microburst winds (Figure IV-3) were plotted. These data then were analyzed by M.M. Wolfson and J.T. DiStefano, who made the final decision as to whether or not a true microburst had occurred. Of the total 3210 algorithm detections, 94.3% were

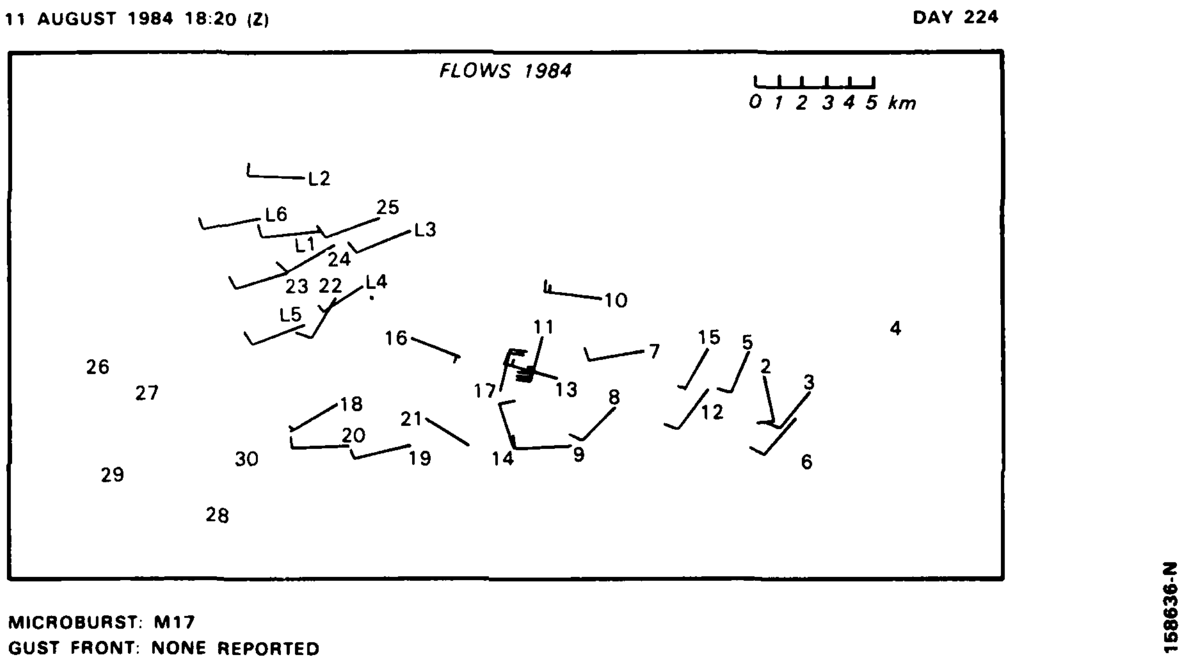

Figure IV-2. Synoptic wind plot for 11 August 1984 at 1820 GMT (see Figure IV-5 for further analysis). Plots like these were generated for every algorithm detection and used to make the subjective final decision as to whether or not a microburst occurred. FAA LLWSAS stations are labelled L1-L6; mesonet stations 1-30. The full wind barbs represent 5 m/s peak/wind speed; the half barbs, 2.5 m/s; and the flag, 25 m/s. The wind speed at station 13 is 27 m/s.

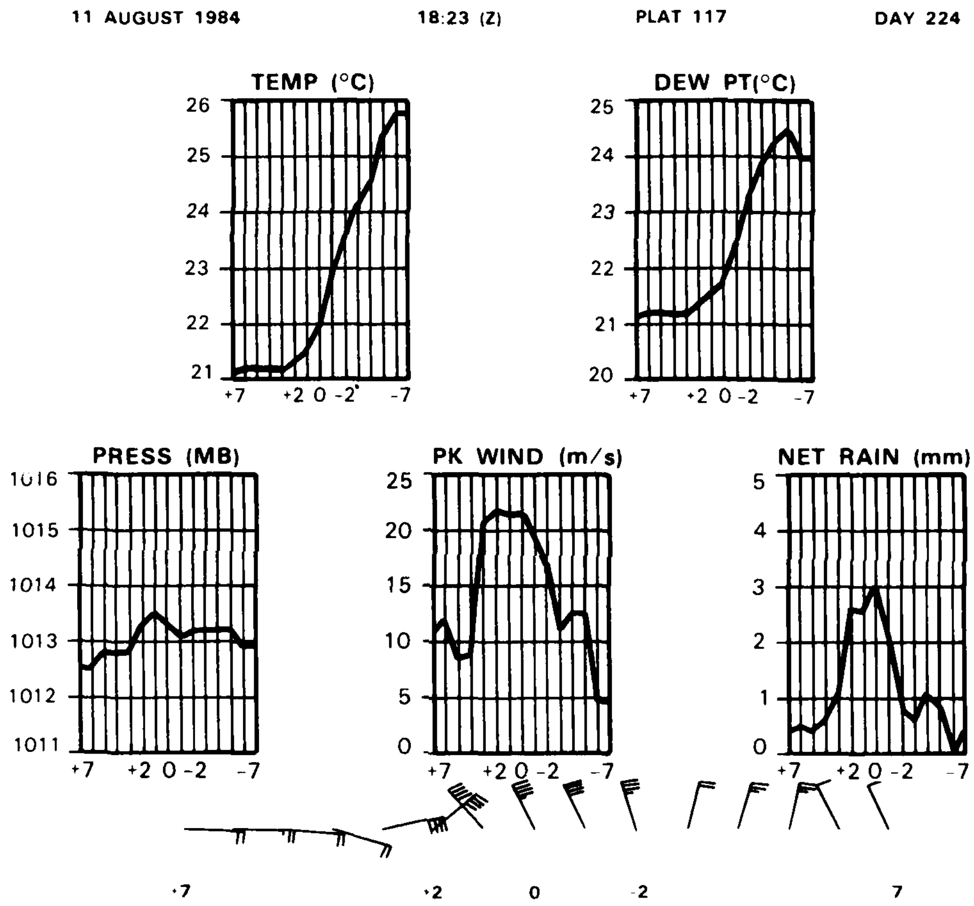

Figure IV-3. Time series plot for station 17 on 11 August 1984. Times earlier than 1823 GMT are plotted at the right and time increases to the left, facilitating a time-space conversion.

eliminated as cold front passages, high gusty winds, or insignificant wind peaks. It was found that a total of 84 or 2.6% were actually gust fronts, and that 102 or 3.1% were true microbursts. In many cases, a gust front signature was evident somewhere in the network at the same time a microburst was occurring.

The count of 102 microbursts represents the total number of stations impacted by microburst winds during the 1984 data collection period. A preliminary analysis of the data allowed an estimate of the total number of individual microbursts to be made. This number totalled 49 for the Memphis seven-month data set. For each day, the estimate of the number of individual microbursts that occurred is written above the station count bar in Figure IV-4.

A paper, entitled "Low-Altitude Wind Shear Characteristics in the Memphis, TN Area Based on Mesonet and LLWSAS Data", was written by M.M. Wolfson, J.T. DiStefano, and Dr. T.T. Fujita for the American Meteorological Society (AMS) 14th Conference on Severe Local Storms, 28-31 October 1985, summarizing the characteristics of low-altitude wind shear in the Memphis area and contrasting these with results from earlier studies in Chicago (NIMROD) and Denver (JAWS). It was shown that microbursts do occur with some regularity in the Memphis area although their characteristics are quite different, on average, from those previously studied in other areas. In general, Memphis microbursts are very 'wet,' occurring with rain rates mostly from one to five inches per hour. Most microbursts expanded rapidly to become 'macrobursts' (>4 km in diameter) with gust fronts at the outflow edges such as the one analyzed on 11 August 1984 and shown in Figure IV-5. There appear* to be fewer microbursts in Memphis than in Denver or Chicago, but their peak wind speeds were higher, their durations longer, and they were mostly accompanied by cooler airflows.

A project report is being compiled by M.M. Wolfson, J. DiStefano, and B.E. Forman describing the mesonet system, data analysis procedures, and results for the Memphis area. Work on more in-depth microburst case studies and 1984 data collection statistics began in the last two weeks of this quarter.

The collection and translation into common format of 1985 mesonet (30 stations) and LLWSAS data continued this quarter with no problems. Two new programs were made part of the routine data translation procedure. The first, completed and made ready for production in April, is an inventory package that counts and computes percentages of missing data values for each sensor and station. It also reports all times for which no data was received from a given station, providing a summary of all missed transmissions. The second program, added in June, plots 24 hours of data from each station so that it easily can be scanned for sensor and/or data problems (Figure IV-6).

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* Considerable caution must be used in comparing the summary statistics from the NIMROD and JAWS programs with our results owing to the differences in mesonet size and sensor spacing as well as in the criteria used to determine whether a microburst had occurred.

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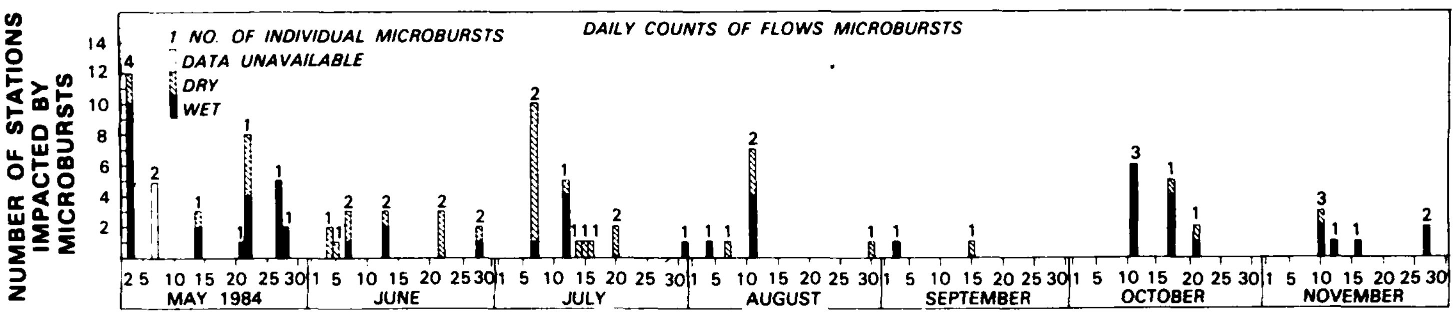

Figure IV-4. Daily count of stations impacted by microbursts during FLOWS, 1984.

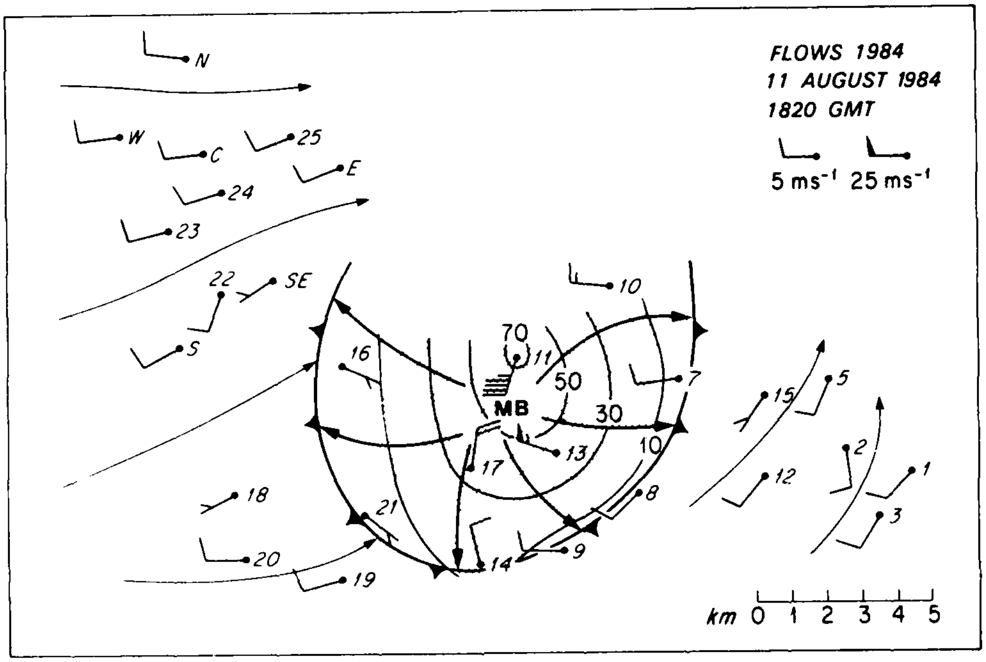

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Figure IV-5. Microburst at 1820 GMT on 11 August 1984. Stippled area represents rain rates >10 mm/hr. Streamlines are shown as thin lines with arrowheads. Mesonet station numbers appear next to wind plots. FAA LLWSAS stations are labeled as: C = center field, E = east, etc. Notice the strong divergence between stations No. 11, No. 17, and No. 13, about 3 km apart. Evidence of microburst winds first appeared at the surface 5 minutes earlier with a divergent 13-15 ms wind at No. 11 and No. 13. The barbed front represents the boundary of the microburst air, which was evident not only in the wind field but also in the temperature field as the edge of the thermal gradient accompanying this event. This rainfall rate reached 70 mm/hr (3 in/hr) at station No. 11, just north of the microburst center (MB).

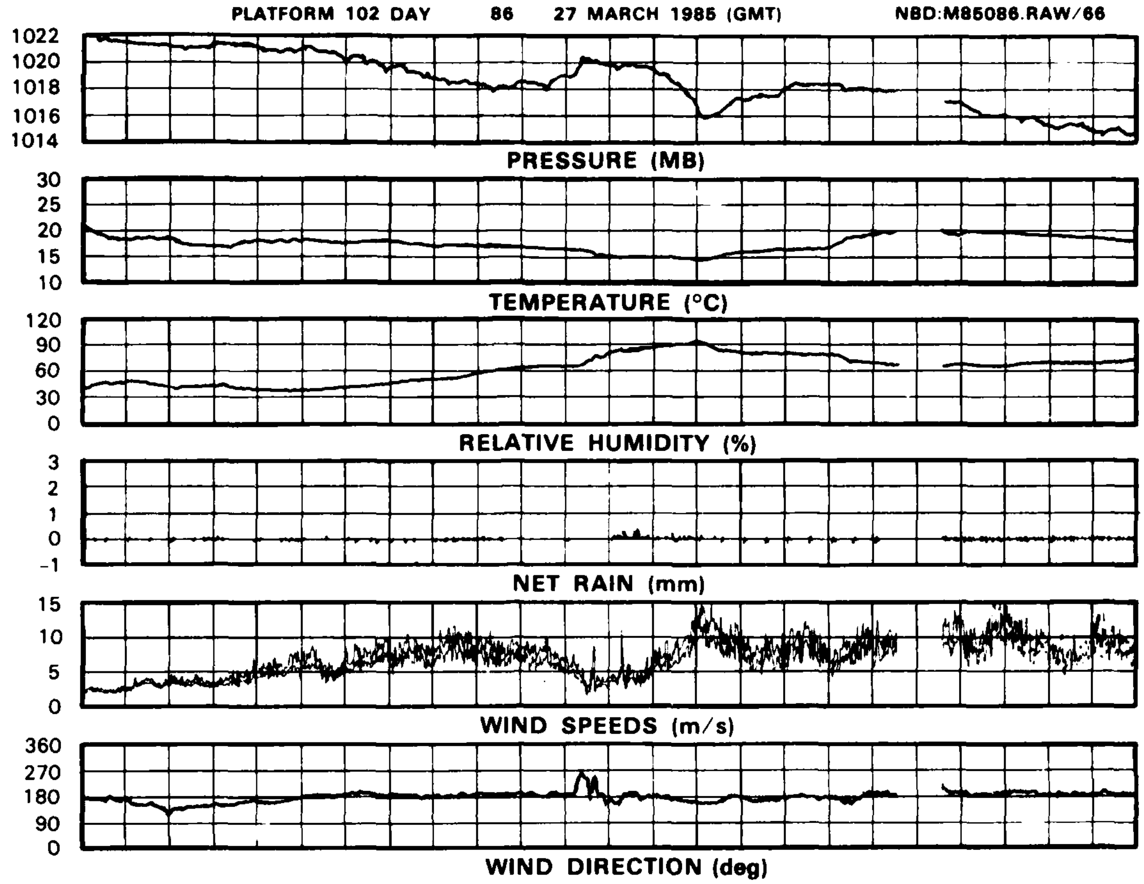

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Figure IV-6. Plot of 24 hours of data from mesonet station No. 2 for 27 March 1985. Notice data from 1832-1932 (2 transmissions) are missing. This plot is used to spot sensor problems or transmission problems. It is easy to see the relationship between the individual variables with this kind of format. Notice also the excellent resolution of wind direction from 180°.

In June, we began reviewing all the mesonet software utilities to eliminate inefficiencies, especially in the data I/O. A special read package was written to store both mesonet and LLWSAS data from an entire day (plus the 30 minutes preceding and following that day) for every station in computer core memory. By using this package for all of the analysis programs, up to a factor of 15 increase in speed will be realized. The new read package was completed this quarter, and some of the most inefficient programs were modified to make use of it. The other programs will be modified during the next quarter to make all of the software consistent.

D. LOW ALTITUDE WIND-SHEAR (LAWS) DETECTION ALGORITHM DEVELOPMENT

The low-altitude wind-shear (LAWS) detection algorithm development effort is aimed at producing an automatic procedure for recognizing hazardous wind-shear events from Doppler weather radar measurements. The current focus of the algorithm development is a simple technique for real-time testing during the 1986 FLOWS experimental program.

The initial version of the algorithm will attempt to identify LAWS hazards (primarily microbursts) by combining several simple feature fields, such as radial shear, azimuthal shear, and local reflectivity maxima. Basic image processing techniques also will be used to spatially smooth and enhance the featuring fields.

This quarter, the availability of an improved layering utility (which converts data from polar to Cartesian coordinates) allowed the bulk processing of several cases to begin. The initial layering and imaging of each case has been started, and will allow a detailed examination of the features of the events included, and their time evolution.

An investigation of the spatial dimension over which radial and azimuthal shears should be calculated has begun. The shear products are key features in the microburst detection process, and the spatial resolution of these products must preserve the important variations in the windfields. Shears calculated at various resolutions on an actual microburst case are being examined to determine the proper trade-off between resolution and estimate variance.

The primary focus for the work next quarter will be the processing of all cases on hand through the basic steps of the initial algorithm, and an analysis of the resulting detection performance.

E. TURBULENCE ALGORITHM DEVELOPMENT

The turbulence detection algorithm studies focus on the validation and refinement of the NEXRAD turbulence detection algorithm in the context of FAA operational use via the Center Weather Processor (CWP). The NEXRAD algorithm (based on work by Labitt[2] at Lincoln, Bohne[3,4] at AFGL, and Lewis[5] characterizes the turbulence in terms of the kinetic dissipation rate, $\epsilon^{1/3}$. The kinetic dissipation rate is related to operationally perceived turbulence by a relationship (summarized in Figure IV-7) due to MacCready[6].

The FAA Air Traffic Service has requested maps depicting the hazardous aviation weather in the altitude sectors used by various en route controllers. These sectors currently are:

(1) low altitude: surface to 24 kft,

(2) high altitude: 24 kft to 33 kft, and

(3) superhigh altitude: above 33 kft.

Accordingly, the current plan is to average the radar turbulence estimates ($\epsilon_r^{1/3}$) vertically to form layers that correspond to the altitude identified above with a 4 $\times$ 4 km horizontal resolution.

The work the past quarter has focused on an initial comparison of MIT weather radar estimates of kinetic dissipation rate ($\epsilon_r^{1/3}$) with several different measures of aircraft turbulence:

(1) $\epsilon^{1/3}$ estimated from pitot tube spatial fluctuation ($\epsilon_p^{1/3}$),

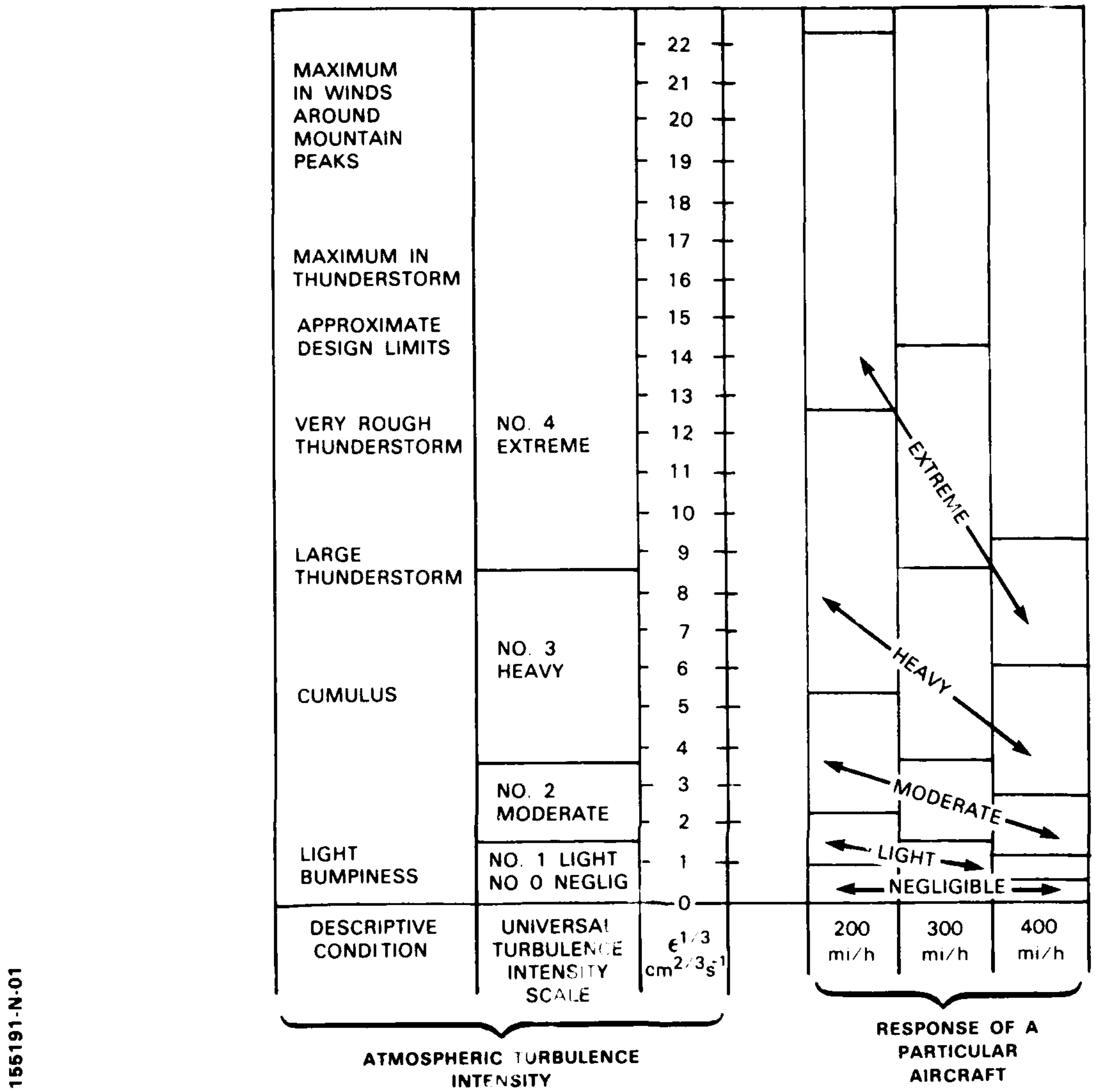

Figure IV-7. Turbulence scale suggested by MacCready[6].

(2) $\epsilon^{1/3}$ estimated from vertical acceleration spatial fluctuations ($\epsilon_a^{1/3}$), and

(3) the derived gust velocity (U_{d_e}) derived from vertical accelerations,

for the UND Citation aircraft flights in the Boston area during the summer of 1983. In the previous quarterly progress report[1], we described computation of $\epsilon_p^{1/3}$, $\epsilon_a^{1/3}$, and U_{d_e}; for the present study, we estimated $\epsilon_r^{1/3}$ by the equation:

$$\epsilon_r^{1/3} = \frac{C_F \, \sigma_u}{A \, a^{1/3}}$$

where C_F = conversion factor

σ_u = spectrum width (ms)

A = Kolmogorov constant

a = radar half power beamwidth (km)

$\approx 0.3\ R\theta$

R = range in km

θ = half power beamwidth in radians (= 0.025 for MIT radar).

To express $\epsilon_r^{1/3}$ as a continuous time series along the aircraft track, the following simple technique was adopted. First, using the fact that the aircraft measurements and positions are expressed in a continuous time series, the duration of the aircraft flying through each individual grid-surface thus can be determined accurately. Second, knowing the time the aircraft is within a specific grid-volume cell, radar quantities thus can be coupled to that specific time associated with the aircraft flight path. Next, by applying the same technique to each grid-volume cell and to each radar scan, a continuous time series of pertinent radar parameters along the aircraft track can be formed for comparison with the aircraft data.

Before presenting the results in detail, the radar data processing and the techniques applied to the radar and aircraft data to prepare them for comparison and correlation analysis will be described. The raw data obtained in each radar volume scan were averaged over a three-dimensional Cartesian grid with variable horizontal $\Delta x = \Delta y$ and vertical spacing Δz, depending upon the desirable spatial resolution. Thus, once the grid size was determined, a single grid volume average value represents all the raw data points contributed to an individual Cartesian grid-volume estimate. In doing so, all of the radar averaged quantities were assumed temporarily invariant for the duration of each radar volume scan. The following important assumptions and data processing technique were used to obtain the results:

(1) It is assumed that turbulence is the primary contributor to Doppler spectrum variance. Other factors, such as wind shear and distribution of fall velocities of the raindrops, also contributing to spectrum broadening, are considered negligible in the simplified analysis. A refined analysis will include these factors, and

(2) Because the radar quantity is an average over the entire volume defined by the grid-scales rather than a point value, the point values of each individual aircraft-derived quantities, such as $\epsilon_p^{1/3}$, $\epsilon_p^{1/3}$, and U_{d_e}, within the grid-volume cell also were averaged. Consequently, comparison of aircraft and radar data is made on the basis of average value within the various grid cells.

As mentioned previously, the layered radar products are essentially volume averages. It is thus important to know the effects of the grid size on the estimates of radar quantities used on the correlation of $\epsilon_r^{1/3}$ (radar) with $\epsilon_p^{1/3}$ (aircraft). The various grid point systems used for the analysis of each selected data set are listed in Table IV-1.

TABLE IV-1 Scales Used in the Analysis of the Layered Radar Quantities				
Case	Horizontal Resolution (km) ΔX	ΔY	Vertical Resolution (km) ΔY	Remarks
I	1	1	1*	Basic scale used for comparing aircraft data with radar data
II	4	4	1*	Evaluating horizontal differences owing to the change in horizontal scale as compared with Case I
IIIa IIIb IIIc	1 1 1	1 1 1	0.3 — 7.3 7.3 — 10.0 10.0 above	Evaluating vertical differences owing to the change in vertical scale as compared with Case I
IVa IVb IVc	4 4 4	4 4 4	0.3 — 7.3 7.3 — 10.0 10.0 above	Evaluating both vertical and horizontal differences

* The vertical resolution ΔZ = 1 km is the layer thickness, which includes the actual aircraft flight height.

For illustrative purposes, one set of the 12 August 1983 data is presented here to show the turbulence spatial patterns and the extent to which the radar derived estimates mime the aircraft measured turbulence. The radar-derived estimate of $\epsilon_r^{1/3}$ from selected horizontal and vertical paths are shown in Figures IV-8 through Figure IV-11. The averaged $\epsilon_a^{1/3}$ and $\epsilon_p^{1/3}$ (aircraft) quantities are plotted in Figures IV-12, 13 and Figures IV-14, 15, respectively. Examination of these figures clearly indicates the radar estimated $\epsilon_r^{1/3}$ values to be considerably larger than the corresponding $\epsilon_p^{1/3}$ and $\epsilon_a^{1/3}$ (aircraft) values, regardless of the grid sizes used in averaging the radar $\epsilon_a^{1/3}$ quantities.

One important feature brought out by Case II (X = Y = 4 km, Z = 1 km) is that $\epsilon_r^{1/3}$ exhibits a substantially different pattern from Case I (X = Y = Z = 1 km). The difference in turbulent pattern is mainly due to the enlargement of horizontal spatial resolution in Case II. As would be expected, the increase in horizontal scale sizes smoothes fluctuations in $\epsilon_r^{1/3}$ quantities and thus results in less temporal variability in Case II than in Case I. The same feature appears in Cases III and IV.

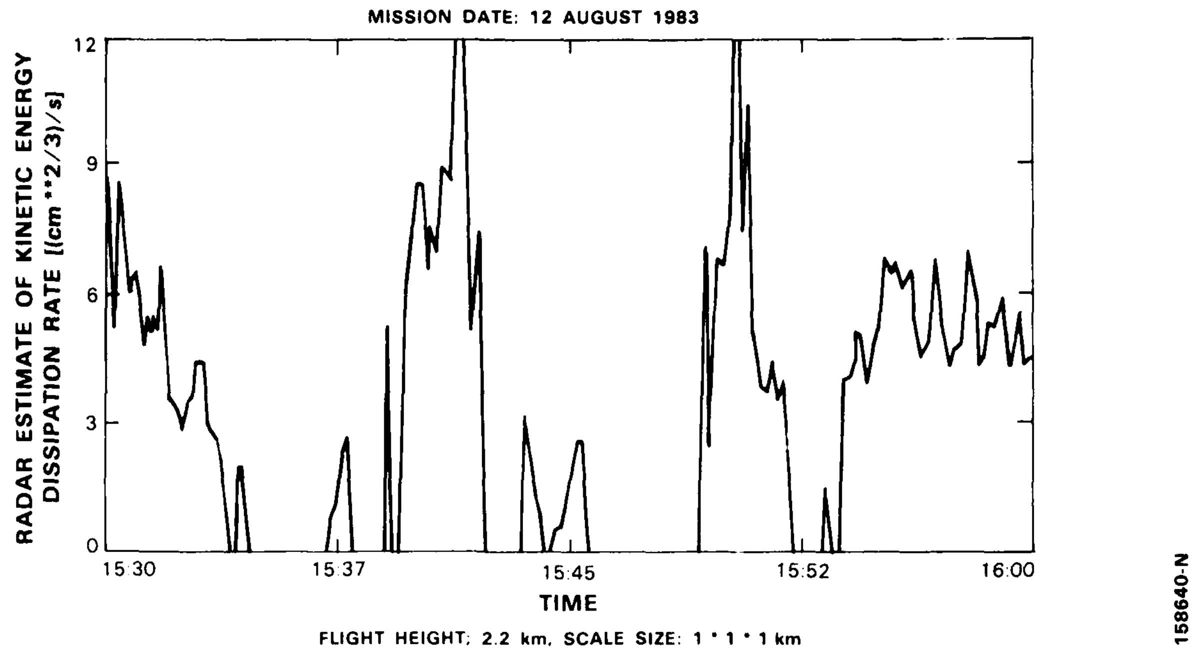

Figure IV-8. Time series of radar estimate of kinetic energy dissipation rate along aircraft track.

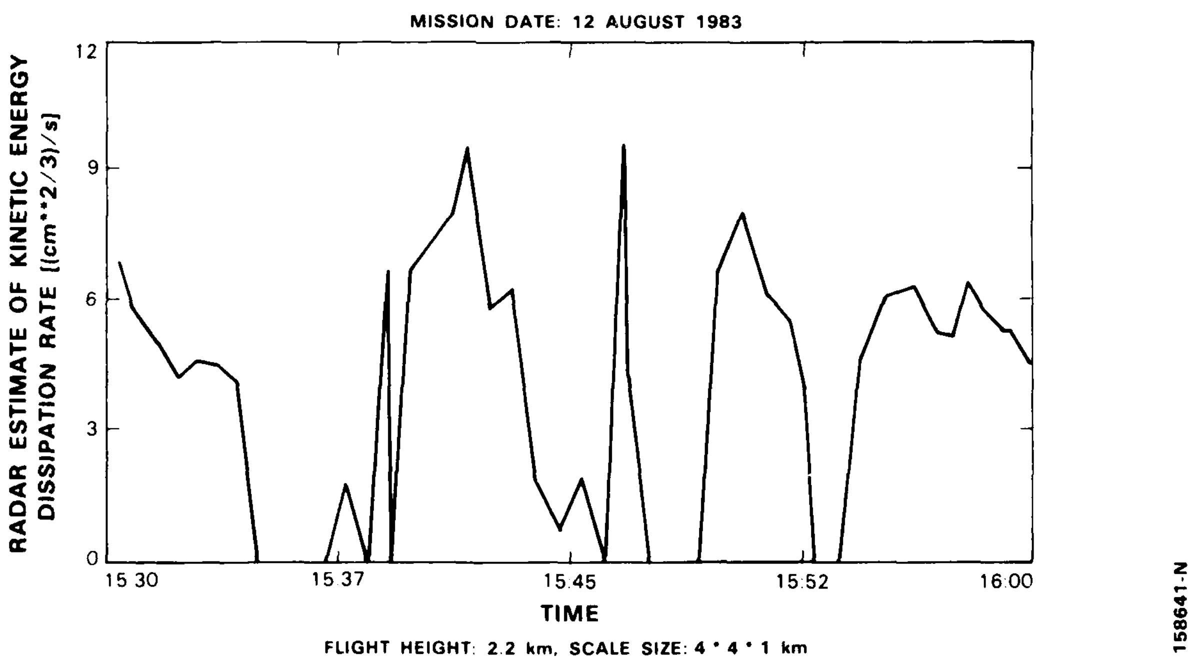

Figure IV-9. Time series of radar estimate of kinetic energy dissipation rate along aircraft track.

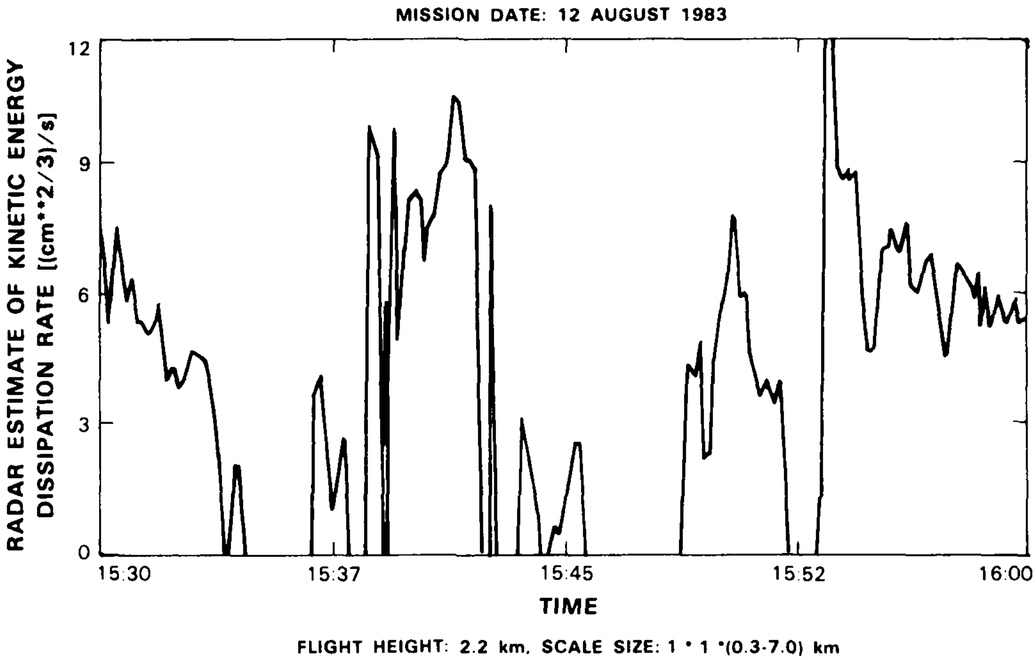

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Figure IV-10. Time series of radar estimate of kinetic energy dissipation rate along aircraft track.

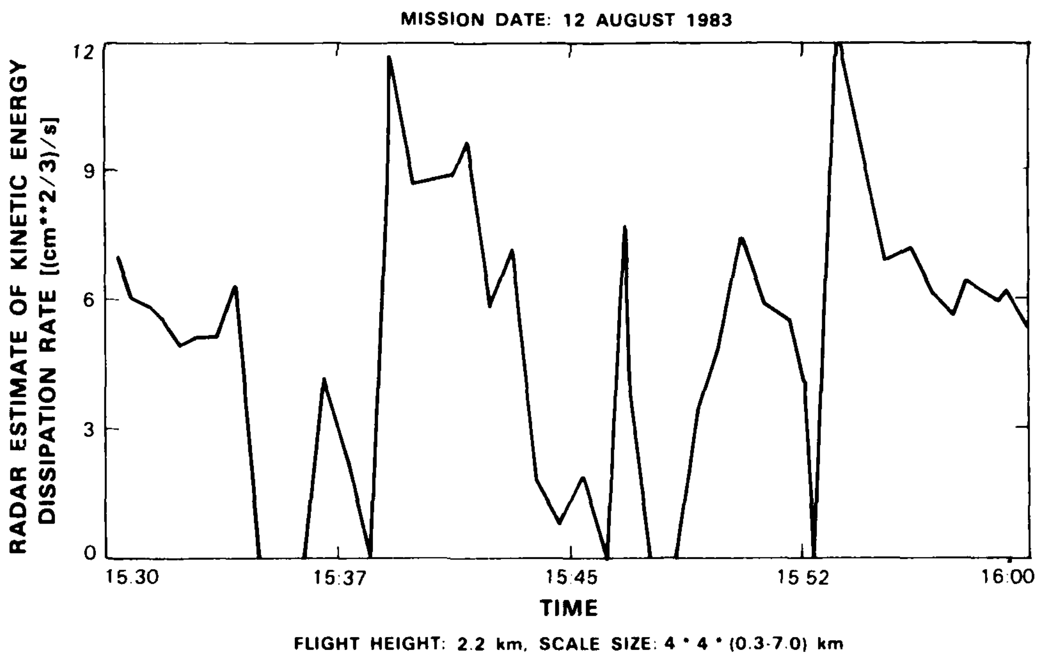

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Figure IV-11. Time series of radar estimate of kinetic energy dissipation rate along aircraft track.

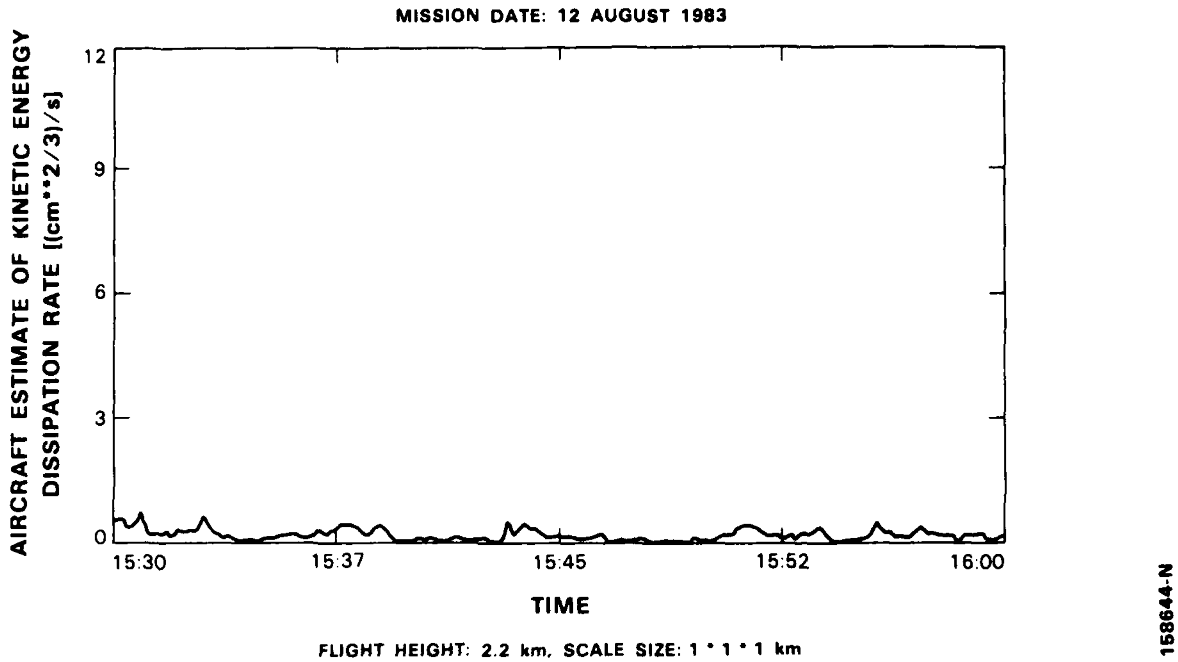

Figure IV-12. Time series of aircraft estimate of kinetic energy dissipation rate computed from acceleration structure function.

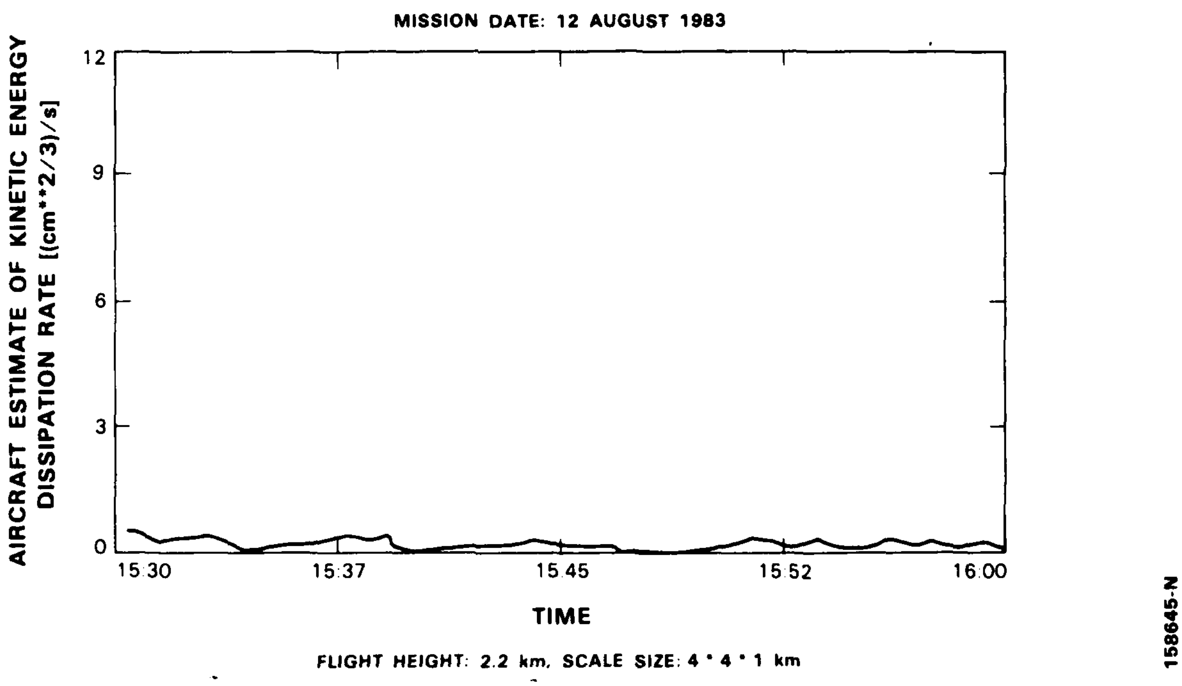

Figure IV-13. Time series of aircraft estimate of kinetic energy dissipation rate computed from acceleration structure function.

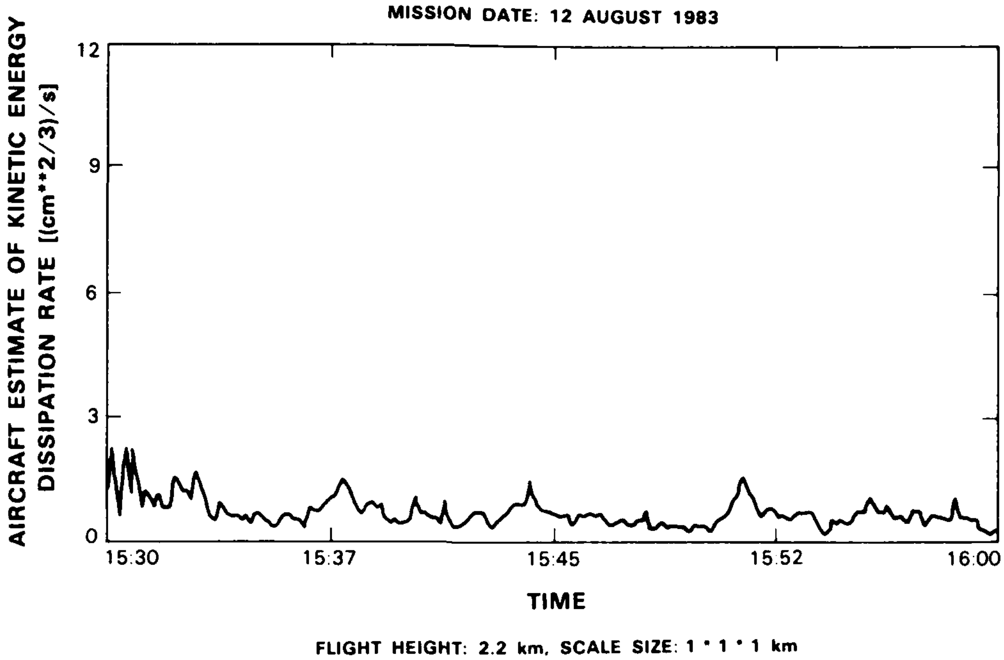

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Figure IV-14. Time series of aircraft estimate of kinetic energy dissipation rate computed from pressure structure function.

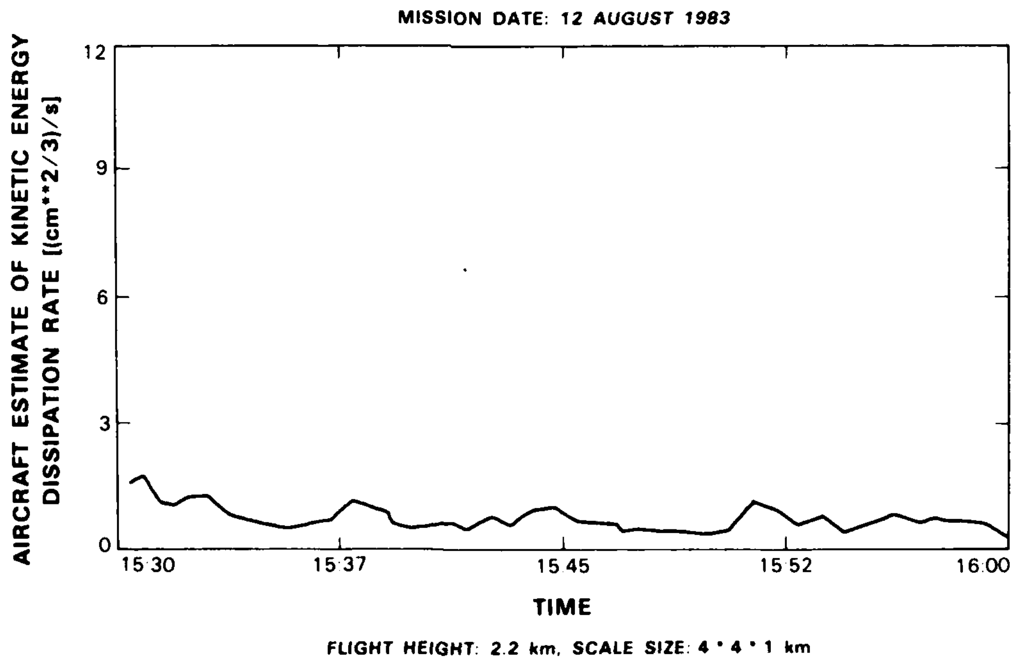

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Figure IV-15. Time series of aircraft estimate of kinetic energy dissipation rate computed from pressure structure function.

In the vertical direction, if the vigorous turbulent regions in the storm are not coincident with the actual aircraft flight height, the use of a thick layer can lead to overestimates in $\epsilon_r^{1/3}$. Consequently, potential inaccuracies in $\epsilon_r^{1/3}$ estimates resulting from significant vertical variation of the turbulence process within a thick layer should be taken into account when interpreting the results of layer products. An inspection of the results shown in Figure IV-8 and Figure IV-10 indicates that the changes in the turbulent patterns with altitude were not significant for the 12 August storm and hence vertical variation in the turbulence levels were probably not the major cause of differences between the aircraft and radar turbulence estimates.

The case above is typical of the three 1983 cases studied to date in that the radar estimates of $\epsilon_r^{1/3}$ are consistently higher than the corresponding aircraft measures. The work this coming quarter will focus on analysis of the remaining 1983 flight cases as well as refinements to the radar processing algorithm described above.

V. ASSESSMENT OF UTILITY OF NEXRAD PRODUCTS FOR ATC USE

The operational utility of the NEXRAD products intended for real-time ATC use has been of concern for sometime inasmuch as none of these products has been assessed in a quasi operational situation. The concerns with these products include:

(1) algorithms for creating CWP products from the NEXRAD products,

(2) horizontal and vertical spatial resolution, and

(3) compensation for the delays between measurement of a given airspace region by NEXRAD and the use of that measurement by ATC personnel.

The Lincoln work in this area has focused on the execution of real-time product demonstrations in which operationally oriented users assess the utility or validity of strawman ATC weather products in a weather impacted ATC environment.

Preliminary discussions were held with the Memphis ARTCC Center Weather Service Unit (CWSU) personnel regarding the evaluation of strawman ATC weather products from NEXRAD during the period September-November 1985. The CWSU personnel were strongly supportive of such a plan.

During these discussions, it was learned that recent changes in airline aircraft capability and flight profiles have resulted in en route ATC being stratified into a three-altitude regime:

(1) low level — surface to 24,000 ft

(2) high level — 24,000 ft. to 33,000 ft, and

(3) super high level — above 33,000 ft

These altitude regimes do not correspond to the current NEXRAD/CWP layered product. Consequently, a letter was written to the FAA CWP program office recommending the use of three layers for the hazardous aviation weather and precipitation maps. This change would necessitate additional layered reflectivity and turbulence products from NEXRAD.

The main focus of work in developing a real-time product capability at the test-bed was the procurement of color work stations reported in Section I. In the next quarter, we will commence programming of these work stations.

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VI. SPECIFICATION OF NEXRAD ALGORITHMS/PRODUCTS FOR CENTRAL WEATHER PROCESSOR (CWP)

The algorithms to generate the NEXRAD products are to be provided to the NEXRAD contractors by the government. Lincoln has been involved in research and development of algorithms to generate:

(1) the layered reflectivity and turbulence products,

(2) correlation tracking of storms,

(3) an extrapolated estimate of reflectivity (typically for time periods of 10 to 30 minutes), and

(4) a vertical cross section of the data along a user specified axis.

Work this quarter focused on areas (2)-(4) above. Additionally, Lincoln is currently active in a Federal Meteorological Handbook (FMH) working group concerned with specification of NEXRAD operations.

A. TRACKING AND EXTRAPOLATION STUDIES

Automated reflectivity tracking and extrapolation received considerable attention during the second quarter of 1985. Discussions with Captain V. Mansur and Major M.R. Snell of the NEXRAD Joint System Program Office (JSPO), held during the NEXRAD Symposium in April, identified needs for substitution of the binary correlation tracker for the previous correlation tracker, separation of the documentation for the correlation tracking algorithm and the SEM (Storm Extrapolation Map, formerly Forecast Reflectivity Map) algorithm, and the ability to produce an SEM based on the tracking information generated either by a correlation tracker or a centroid tracker (i.e., the NEXRAD 'storm package'). Several weeks later, the results of the NEXRAD Algorithm Review became available indicating both a degree of confusion with respect to the computational requirements and necessity of a correlation tracking algorithm, and a dissatisfaction with the algorithm's documentation within the NEXRAD community.

In response, Lincoln Laboratory prepared several documents that were supplied to the JSPO and to those agencies commenting on the correlation tracker in the course of the algorithm reviews:

(1) NEXRAD algorithm documentation for the binary correlation tracker, intended to replace the previous correlation tracking algorithm,

(2) A functional specification for the SEM product,

(3) A report detailing the results of the timing and performance evaluations conducted during the first quarter of 1985, contrasting the computational requirements and tracking skill of the basic and binary correlators, and

(4) Individual responses to the agencies commenting on the correlation tracking algorithm during the NEXRAD reviews — addressing the issues that each had identified for the algorithm, and providing theoretical and empirical arguments demonstrating the necessity of a correlation-type tracker and the computational modesty of a binary correlator operating on the NEXRAD Layer Composite Reflectivity Product.

In addition, a new algorithm for the SEM product, with the capability to produce extrapolated reflectivity maps on the basis of either the correlation or centroid trackers, was developed. A NEXRAD Algorithm Description was prepared for this SEM algorithm, and will be released subsequent to performance and verification evaluations currently in progress.

During June, representatives from Lincoln and the FAA CWP office attended a meeting at the JSPO to discuss the integration of the binary correlator and SEM algorithms into the NEXRAD System. At that time, the JSPO indicated that the binary correlator might be more readily included in the Limited Production Phase system if it possessed a corresponding NEXRAD Product. As the correlator is intended as a 'front end' to the SEM algorithm, Lincoln agreed to supply the JSPO with a product description for the SEM — this has been done — and to provide the JSPO with timing and performance data for the Lincoln implementation of the SEM product by 15 August 1985.

The current status of tracking and prediction studies at Lincoln is as follows. Development of the binary correlator is essentially completed; the algorithm is currently undergoing independent verification and testing at PROFS, and the SASC documentation for the algorithm has been finalized. A FORTRAN-77 implementation for the Lincoln SEM algorithm is being written, and will be used both to the verify the algorithm and to provide the JSPO with the information mentioned above.

In mid-June, a study, to be directed by Professor Robert Crane of Dartmouth, was funded to evaluate the feasibility of an automated algorithm for the identification of regions of convective growth and decay in the context of the NEXRAD System. Such an algorithm can be expected to improve automated tracking and extrapolation performance significantly through the incorporation of information concerning storm dynamics.

B. ARBITRARY VERTICAL CROSS SECTION ALGORITHM

The Boston Area NEXRAD Demonstration in 1983 identified a need to provide better visualization of vertical structure along live storms. In response to this need, work has commenced to develop an arbitrary vertical cross section utility for Cartesian PPI radar data. The program, AVX, allows the user to view the vertical structure of a PPI volume scan along a given line in the X-Y plane. This program will be useful in analyzing the internal structure of weather in data analysis at Lincoln and may be used in the test-bed operation.

The first implementation of AVX is flexible and very interactive. This version has been tested, demonstrated, and reviewed.

The second version of AVX has been designed and reviewed. This version will be faster and less interactive than the initial program. Polar data, as well as layered data, will be used. It is expected that polar data will be the fastest to process. Timing measurements will be made with polar and Cartesian data when the software is finished. These timing estimates together with a product functional description will be provided to the NEXRAD JSPO and the FAA CWP program office in the next quarter.

C. FEDERAL METEOROLOGICAL HANDBOOK SUPPORT

A new volume of the Federal Meteorological Handbook, designated as FMH-11, is being prepared to serve as the operational handbook for the NEXRAD System. The task of writing this document has been delegated to five 'Working Groups', each of which has responsibility for certain portions of FMH-11 and is comprised of representatives from DoT, DoC, DoD, the IOTF, and technical advisors from institutions such as Lincoln Laboratory. A representative from Lincoln Laboratory is serving on Working Group E (WGE), which has been tasked to write the sections of FMH-11 specifying operational modes, scanning strategies, product mixes, product shedding priorities, and mode selection/deselection criteria.

The first meeting of WGE took place in Kansas City, Missouri, in late May. As evaluations conducted during the Boston Area NEXRAD Demonstration (BAND) and at the IOTF indicated that the precipitation scanning strategy specified in the NTR — a volume scan consisting of 14 elevation scans in five minutes (14/5) — would not provide for satisfactory algorithm performance, a primary precipitation scanning strategy of 18/6 was specified by WGE. The 18/6 strategy consists of a standard 17-tilt volume scan with an additional low-level scan at the temporal midpoint of the volume scan to provide for a low altitude data update rate that is consistent with the lifetimes of those shear phenomena of interest to the FAA.

Since the 14/5 precipitation strategy of the NTR was intended to be used for RPG and RDA sizing estimates, the JSPO indicated concern that the 18/6 strategy might not be consistent with the Validation Phase NTR. Lincoln and USAF's HQ MAC performed analyses confirming that the RDA data rate and RPG processing requirements deriving from the 18/6 strategy were comparable to, and perhaps slightly less stringent than, those deriving from a 14/6 strategy. RPG storage requirements were increased marginally under the 18/6 strategy. Additional analyses demonstrated that the NTR estimate accuracy requirements could be met for an 18/6 strategy in a manner essentially consistent with all other portions of the Validation Phase NTR, and that a representative 18/6 strategy reduced the maximum vertical gap in the coverage below 15 km — the altitude regime of interest for storm initiation — to 0.6 km, whereas the corresponding value for a representative 14/6 strategy is 1.8 km.

The next meeting of WGE is scheduled to occur on 15 and 16 July 1985 in Olive Branch, Mississippi. The draft WGE document will be completed at that time. Lincoln Laboratory will serve as host for this meeting and will provide a tour of the FL-2 and UND radar sites to the WGE participants.

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GLOSSARY

A/D	Analog-to-Digital (signal conversion)
AFGL	Air Force Geophysics Laboratory
AGC	Automatic Gain Control
APU	Auxiliary Processing Unit
ARTCC	Air Route Traffic Control Center
ASR	Airport Surveillance Radar
ATC	Air Traffic Control
AVSE	Air Vehicle Survivability Evaluation
BAND	Boston Area NEXRAD Demonstration
BCD	Binary-coded decimal
CAR	Cartesian Format
CD	Common Digitizer
CF	Common Format
CFT	Common Radar Data Format
CIDF	Lincoln Laboratory Common Instrument Data Format
COHMEX	Cooperative Huntsville Meterological Experiment
COHO	Coherent Local Oscillator
CPU	Central processing unit
CWP	Central Weather Processor
CWSU	Center Weather Service Unit
DAA	Data Acquisition and Analysis (Processor)
dBz	Unit of weather reflectivity
DCP	Data Collection Platform (implies transmitter to GOES satellite)
FAA	Federal Aviation Administration
FAATC	Federal Aviation Administration Technical Center
FIR	Finite Impulse Response
FL-2	FAA/Lincoln Laboratory Test-Bed Doppler Radar
FLOWS	FAA/Lincoln Operational Weather Studies
FMH	Federal Meterological Handbook
FTP	File-Transfer Protocol
GOES	Geostationary Operational Experimental Satellite
INS	Inertial navigation system
IOTF	Interim Operational Test Facility
IP	Internet Protocol
I/Q	In-Phase and Quadrature
JAWS	Joint Airport Weather Studies
JSPO	Joint System Program Office (for NEXRAD program)

LAWS	Low-Altitude Wind Shear
LLWSAS	Low-Level Wind-Shear Alert System
MB	Megabyte
MB	Microburst
Mesonet	Refers to a network of automatic weather stations with a close, i.e., a 'mesoscale' spacing. Lincoln's spacing might be called 'microscale.'
MIST	Microburst and Severe Thunderstorm (Project)
MPM	Multi-Port Memory
NCAR	National Center for Atmospheric Research, Boulder, Colorado
NEXRAD	Next Generation Weather Radar
NIMROD	Northern Illinois Meteorological Research on Downbursts
NSSL	National Severe Storms Laboratory, Norman, Oklahoma
NTR	NEXRAD Technical Requirements
NWS	National Weather Service
PE	Processing Element
P.E.	Perkin-Elmer
PPI	Plan Position Indicator
PRF	Pulse Repetition Frequency
PROFS	Prototype Regional Forecasting System
RAM	Random-Access Memory
RF	Radio Frequency
RFI	Request for information
RHI	Radial Height Indicator
RPA	Radar Product Generator
RPG	Radar Data Acquisition
RTS	Real-time system
SASC	Systems and Applied Sciences
SEM	Storm Extrapolation Map
S/N	Signal-to-Noise
SPACE	Satellite, Precipitation, and Cloud Experiment
TCP	Transmission Control Protocol
TDWR	Terminal Doppler Weather Radar
UND	University of North Dakota
VSWR	Voltage standing-wave ratio
VTM	Virtual Task Management
WGE	Working Group E

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